School of Occupational Therapy, Social Work and Speech Pathology
The Cooperative Research Centre for Living with Autism (Autism CRC)

# Reconceptualising Interventions for Supporting the Social Emotional Skills of Autistic Adults

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**This thesis is presented for the Degree of**
**Doctor of Philosophy of Curtin University**

**June 2020**

# Declaration

To the best of my knowledge and belief, this thesis contains no material previously published by any other person except where due acknowledgment has been made. This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) - updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Numbers HR52/2012 and HR38/2016.

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| Signed | Julia Tang<br>(Candidate) | 27.05.2020 |

# Acknowledgements

Firstly, I would like to extend my thanks and acknowledgement to the autistic individuals, health professionals and educators who participated in this study. I truly appreciate your valuable insights and feedback on suitable social emotional supports for autistic adults. Your commitment and dedication to autism research is truly inspiring.

My deepest gratitude to my thesis committee, Professor Sonya Girdler, Dr Marita Falkmer, Dr Nigel Chen, Professor Sven Bölte and Professor Tele Tan. Your guidance and encouragement throughout these years is greatly appreciated. To Sonya, I am always in awe by your passion and determination in research. Thank you for constantly reassuring me that we can achieve the impossible. We certainly made it in the end! Thank you for spending long hours proof reading my countless drafts. I could not have done this without you. To Marita, your observant and caring nature is very much appreciated. You are the catalyst for facilitating my personal and professional development. Thank you for your continued support, encouragement and inspiring me to make a genuine difference to the autistic community. To Nigel, thank you for imparting your expertise in eye tracking and statistical methods. I believe your detailed and analytical approach, plus your critical thinking skills were immensely helpful in shaping this project. To Sven, thank you for supporting my PhD research projects from afar. Your contributions and effort in sharing your vast knowledge in autism research have been incredibly valuable. Thank you for broadening my research knowledge. To Tele, your expertise in technology and advice on research resources is greatly appreciated. Thank you for your continuous dedication to harness the strengths of autistic individuals.

A special mention to Professor Torbjorn Falkmer. You were my first entry into the research world, and have instilled me with a passion to continue my research journey. Although you are not in my supervision team, you have always gone above and beyond to support me. Thank you for your mentorship and for bringing positivity to the Curtin Autism Research Group.

My heartfelt thanks to the many people who have supported this research project. Tatiana, thank you for dedicating your time in recruitment and mentoring the autistic adults. The feedback received regarding MindChip™ is a testament to what an amazing person you are. Dr Richard Parsons, thank you for sharing your statistical expertise. Your guidance during data analysis is appreciated. A special thanks to Melissa Black. I can't believe that it has been eight years since we started this research journey together. Thank you for enduring my quirkiness over the years. Thank you for leading the way for women in research. You are a true inspiration. To my many friends whom I have gained over the years, Bahareh Afsharnejad, Alison Blane, Angela Camberlain, Alex Goh, Megan Hatfield, Matt Jones, Yi Huey Lim, Wee Lih Lee, Tanya Picen, Melissa Scott, Jia White, and many more. PhD life would be quite dull without you. Thank you for providing endless laughter, continuous encouragement and sharing your knowledge when I was feeling clueless. I will forever treasure our PhD 'therapy' discussions- I believe this kept my sanity intact throughout my PhD research.

To the neurodiverse team, Dr Kartik Iyer, Angus Campbell, Zachary Kidd, Krystal McDonald, Aiden McIntosh, Cameron Minissale, and Brendan Pollastri. The cohesiveness of the neurodiverse team is the reason that this project was awarded the Autism CRC Best Inclusive Practice Award. Each one of you are highly skilled and talented. Thank you for dedicating your valuable time and sharing your creativity. This team is my first insight into co-production research, and it has given me the push to improve my involvement with autistic individuals in research. I cannot thank you enough.

I would like to acknowledge the financial support from the Australian Government Research Training Program Scholarship for funding my postgraduate studies and conference attendance. I also acknowledge the financial support of the Cooperative Research Centre for Living with Autism (Autism CRC), established and supported under the Australian Government's Cooperative Research Centres Program. I appreciate the support from the Autism CRC for providing me with countless networking opportunities and providing insights into research beyond my field. Thank you for your commitment to enrich the learning experiences of PhD scholars. Capstone

Editing provided copyediting and proofreading services for Chapter 1 and 8 of this thesis, according to the guidelines laid out in the university-endorsed national ‘Guidelines for Editing Research Theses’.

My utmost gratitude to my family. Mum and Dad, thank you for encouraging me to strive for a better education. More than a decade ago, you sacrificed yourselves for your children so each one of us can have an education. Without your sacrifices, I would not have ventured into the postgraduate world. Thank you for shaping me into a better person. My siblings, Gabriel, Angel, Daniel, Jacob and Sylvia- Thank you for volunteering to be my research ‘guinea pigs’ throughout my research career. You provided me with endless inspiration for my research projects. Your patience to listen to my research ramblings is very much appreciated.

To Teh, no words can describe my immense gratitude for your unwavering support throughout this journey. Through unexpected circumstances, our paths crossed. Since then, you have been my never ending source of joy and strength. Thank you for lifting me up during my darkness moments. You bring positive energy into my life. I look forward to doing more life adventures with you.

# Dedication

To my parents, Joseph Tang and Helen Chew. Thank you for your undying love for your children. Your perseverance in confronting many challenging circumstances is truly inspiring. You both are the true definition of strength and love. Your constant support, prayers and unexpected small gestures of love motivated me to persevere during difficult moments. I dedicate this thesis to you.

# List of Publications

## Published

Tang, J. S. Y., Chen, N. T. M., Falkmer, M., Bölte, S., & Girdler, S. (2019). A systematic review and meta-analysis of social emotional computer based interventions for autistic individuals using the serious game framework. *Research in Autism Spectrum Disorders*, Advance online publication. https://doi.org/10.1016/j.rasd.2019.101412. Impact factor 2.907

Tang, J. S. Y., Falkmer, M., Chen, N. T. M., Bölte, S., & Girdler, S. (2018). Designing a serious game for youth with ASD: Perspectives from end-users and professionals. *Journal of Autism and Developmental Disorders*, *49*(3), 978-995. https://doi.org/10.1007/s10803-018-3801-9. Impact factor 3.341

Tang, J. S. Y., Chen, N. T. M., Falkmer, M., Bölte, S., & Girdler, S. (2019). Atypical visual processing but comparable levels of emotion recognition in adults with autism during the processing of social scenes. *Journal of Autism and Developmental Disorders*, *49*(10), 4009-4018. https://doi.org/10.1007/s10803-019-04104-y. Impact factor 3.341

Tang, J. S. Y., Falkmer, M., Chen, N. T. M., Bölte, S., & Girdler, S. (2020). Development and feasibility of MindChip$^{TM}$: A social emotional telehealth intervention for autistic adults. Journal of Autism and Developmental Disorders. Advance online publication. https://doi.org/10.1007/s10803-020-04592-3

## Submitted

Tang, J. S. Y., Chen, N. T. M., Falkmer, M., Bölte, S., Black, M. H., & Girdler, S. (2020). Naturalistic social cognition performance and visual scanning in autistic adults. Manuscript submitted for publication.

# List of Conference Presentations

Tang, J., Falkmer, M., Bölte, S., & Girdler, S. (2016, August). *Designing a serious game for youth on the autism spectrum: Perspectives from end-users and professionals*. Paper presented at Mark Liveris Student Research Seminar, Perth, Western Australia.

Tang, J., Falkmer, M., Bölte, S., & Girdler, S. (2017, May). ‘If you make the story good enough, it becomes a reward’: Designing a social emotional Serious Game from the perspectives of youth on the autism spectrum and professionals. Poster presented at International Society of Autism Research, San Francisco, United States.

Tang, J., Falkmer, M., Bölte, S., & Girdler, S. (2017, September). ‘If you make the story good enough, it becomes a reward’: Designing a social emotional Serious Game from the perspectives of youth on the autism spectrum and professionals. Poster presented at Mark Liveris Student Research Seminar, Perth, Western Australia.

Tang, J., Iyer, K., Falkmer, M., Bölte, S., & Girdler, S. (2017, December). *The experience of developers in developing a computer game for people on the autism spectrum*. Poster presented at Australasian Society for Autism Research, Perth, Western Australia.

Tang, J., Falkmer, M., Bölte, S., & Girdler, S. (2017, December). *Designing a serious game for youth on the autism spectrum: Perspectives from end-users and professionals*. Poster presented at Australasian Society for Autism Research, Perth, Western Australia.

Tang, J., Chen, N. T. M., Falkmer, M., Bölte, S., & Girdler, S. (2018, May). ‘Gaming seriously!’: A systematic review and meta-analysis of the influence of Serious Game elements on the effectiveness of social-emotional computer based interventions in autism. Poster presented at International Society of Autism Research, Rotterdam, Netherlands.

# Awards

- Best Poster Presentation Award, Mark Liveris Student Research Seminar, 2016.
- Best Three Minute Poster Presentation Award, Mark Liveris Student Research Seminar, 2017.
- Best Inclusive Practice Award for Social Emotional Computer-based Intervention Project. Cooperative Research for Living with Autism (Autism CRC), 2017.

# Statement of Contributions

The nature and extent of the intellectual input by the candidate and co-authors has been validated by all authors:

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| Signed | Professor Sonya Girdler<br>(Primary Supervisor) | 28.05.2020 |
| Signed | Dr Marita Falkmer<br>(Secondary Supervisor) | 28.05.2020 |
| Signed | Dr Nigel Chen<br>(Secondary Supervisor) | 28.05.2020 |
| Signed | Professor Sven Bölte<br>(Secondary Supervisor) | 12.06.2020 |
| Signed | Dr Melissa Black<br>(Co-author) | 28.05.2020 |

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# Abstract

Social participation is inevitable in everyday social environments. Similar to non-autistic individuals, autistic adults express the same desire to establish meaningful social interactions. However, they often face many challenges in social participation, including elevated levels of social isolation and reduced quality of life. In Australia, 64.8% of autistic individuals reported lower levels of adaptive functioning, requiring greater assistance in social domains, including 'cognitive or emotional' (73.7%) and 'communication' (48.5%). The social participation challenges experienced by autistic adults may be partly attributed to social emotional skills difficulties. Two main intervention approaches, facilitator mediated and computer based have been developed, aiming to support the social emotional skills of autistic individuals. While evidence for both of these social emotional interventions are promising, results supporting the generalisation of learnt skills to everyday social interactions is limited, with a clear need for developing age-appropriate and engaging social emotional content specifically for autistic adults. Additionally, the variability in intervention delivery and inconsistent measurement frameworks for evaluating generalisation outcomes of social emotional interventions further limits understanding of the true efficacy of these interventions for autistic individuals. Therefore, the overarching aim of this thesis was to develop a facilitator mediated social emotional program paired with a computer based intervention (CBI) and evaluate the feasibility of combining both approaches in targeting the social emotional skills of autistic adults. The Medical Research Council framework was adopted, guiding the three phases of this thesis.

Phase 1: *Scoping the problem*, comprised a systematic review and meta-analyses examining existing social emotional CBI for autistic individuals (Chapter 2). Narrative synthesis of 24 social emotional CBI revealed variability in applying serious game design and learning content for addressing the social emotional difficulties of autistic adults. Meta-analyses of 17 controlled efficacy studies evaluating social emotional CBI for autistic individuals revealed positive effects in utilising computer based modalities for

targeting the social emotional understanding of autistic individuals. However, definite conclusions for CBI in improving outcomes relating to generalising learnt skills to everyday social interactions is limited, likely in part attributed to the limited application of standardised outcome measures. Increased application of serious game principles was associated with improved generalisation of skills to real world social interactions, pointing to the utility of the serious game framework in CBI development. Findings in phase one highlighted that further development of CBI for autistic adults is required for improving the engagement and generalisation of learnt skills to everyday social interactions.

Phase 2 outlined the *development* phase, constituting two arms. The first arm aimed to explore appropriate social emotional learning content specifically for autistic adults. Focus groups (Chapter 3) were conducted to explore the perspectives of autistic youth and professionals on suitable design features and content for a social emotional CBI. While both stakeholders held differing perspectives in some aspects of the social emotional intervention design, both perspectives are crucial in identifying appropriate content for improving the motivational and pedagogical value of social emotional interventions. Both autistic youth and professionals highlighted the importance of embedding realistic social emotional scenarios and goals into social emotional interventions. Professionals further emphasise the importance of exploring problem solving strategies during challenging social emotional situations.

The second arm in Phase two constitutes an introductory chapter of eye tracking methodology (Chapter 4) and two case controlled studies (Chapters 5 and 6) investigating suitable social emotional ecologically valid assessments for measuring changes in response to a social emotional intervention. Chapter 4 provides an overview of eye tracking as a tool for assessing overt visual attention. Embedding eye tracking measurements in social emotional assessments has the potential to broaden understanding of the social emotional abilities of autistic adults. Chapter 5 investigates the Reading in the Mind in Films test, finding comparable emotion recognition accuracy performance between autistic and non-autistic adults, despite differences in visual strategies while processing naturalistic social scenes. The non-significant group differences in social emotional accuracy suggest limited suitability of the Reading in the Mind in Films test in detecting changes following a social emotional intervention. Chapter 6 investigated the performance of autistic and non-autistic adults on the Movie Assessment of Social Cognition. Autistic adults demonstrated poorer accuracy compared to non-autistic adults. Eye tracking results revealed autistic adults gazed less at the head region with increased fixation to the non-social regions compared to the non-autistic adults. Findings suggest that the Movie Assessment of Social Cognition may be more responsive in detecting any social emotional changes, thus a more appropriate outcome measure in phase three.

Phase 3 described the *feasibility* of the MindChip™ program, a facilitator mediated program conducted in conjunction with a social emotional CBI (Chapter 7). The theoretical underpinnings of the MindChip™ program was described. A pilot randomised controlled trial evaluated the feasibility of the MindChip™ program with an existing social emotional CBI, Mind Reading©. The trial comprised 25 autistic adults, comparing a group receiving both the MindChip™ program and Mind Reading©, with autistic adults receiving the Mind Reading© program only. Results demonstrated good acceptability and feasibility of the MindChip™ program. However, poor acceptability of the Mind Reading© program was reported, mainly due to the significant technical issues experienced and the outdated nature of the program. The results further revealed that the group receiving the MindChip™ program and Mind Reading© demonstrates preliminary effectiveness in improving the outcomes suggesting generalisation of learnt skills to real world social interactions. Findings suggest the MindChip™ program is a promising tool for facilitating the social emotional understanding of autistic adults.

Overall, the findings of this thesis provide implications for reconceptualising interventions supporting the social emotional understanding of autistic adults. This thesis also provides evidence for implementing serious game design principles in social emotional CBI, an essential component for improving the engagement and generalised learning of autistic adults. The findings of this thesis further add knowledge relating to suitable intervention approaches and age-appropriate social emotional learning content for autistic adults. Further, measurement frameworks comprising standardised outcome measures containing naturalistic social interactions, and qualitative methods are indicated, providing a more holistic understanding of the extend of social emotional interventions in generalising outcomes to everyday social interactions. This research provides insights into the variability of social emotional skills among autistic adults, necessitating the importance of switching from a *deficit* paradigm to adopting intervention approaches acknowledging social emotional neurodiverse *differences*. Findings further highlight the importance of individualised facilitator mediated approaches combined with computer based approaches in enabling autistic adults to discover their social emotional strengths and explore personally relevant strategies in varying social emotional situations.

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# List of Abbreviations

| | |
|---|---|
| ADIR-R | Autism Diagnostic Interview (Revised) |
| ADOS | Autism Diagnostic Observation Schedule |
| ANOVA | Analysis of variance |
| AQ | Autism Quotient |
| AS | Asperger's Syndrome |
| ASD | Autism Spectrum Disorders |
| Autism CRC | Cooperative Research Centre for Living with Autism |
| CBI | Computer-based intervention |
| CONSORT | Consolidated Standards of Reporting Trials |
| DASS | Depression, Anxiety, and Stress Scale |
| DSM-IV | Diagnostic and Statistical Manual of Mental Disorders (Fourth Edition) |
| DSM-5 | Diagnostic and Statistical Manual of Mental Disorders (Fifth Edition) |
| EQ | Empathy Quotient |
| ERSE | Emotion Recognition Self-Efficacy Scale |
| ICC | Intra-class coefficient |
| IQ | Intelligence Quotient |
| LSAS | Liebowitz Social Anxiety Scale |
| MASC | Movie for the Assessment of Social Cognition |
| MR | Mind Reading |
| MRC | Medical Research Council |
| PDD-NOS | Pervasive Developmental Disorder (Otherwise Not Specified) |
| RMET | Reading the Mind in Eyes Test |
| RMFT | Reading the Mind in Films Test |
| ROC | Receiver operating characteristic |
| SMI | SensoMotoric Instruments |
| SRS | Social Responsiveness Scale |
| SST | Strange Stories Test |
| ToM | Theory of Mind |
| WASI | Wechsler Abbreviated Scale of Intelligence |

# Chapter 1 : Introduction

# Background

This research project was funded by the Cooperative Research Centre for Living with Autism (Autism CRC), the first nationally recognised cooperative effort for autism research in Australia. The Autism CRC's mission encompasses implementation of research programs across the developmental lifespan from early years, school age and adulthood, through inclusive practices. This research was conducted under Program 3, prioritising research for improving the adult outcomes in tertiary education, employment, mental wellbeing and community participation.

While the term 'Autism Spectrum Disorder' (ASD) is widely adopted among health professionals and researchers, a large proportion of the autistic community has voiced dissatisfaction with this term its used (1). The Cooperative Research Centre for Living Autism (Autism CRC) has endorsed the term 'autistic' for describing an individual diagnosed with ASD, based on the preferences of the community (2). Given that this research project falls under the auspices the Autism CRC, the 'autistic' terminology is employed, except when referencing the ASD diagnostic criteria. It is important to note that this thesis comprises five journal manuscripts, with varying requirements in regard to their preferred terminology. Chapters within this thesis may employ different autism terminology depending on the journal requirements.

# Autism Spectrum Disorders

ASD is a lifelong neurodevelopmental condition with symptoms presenting in early development. According to the Diagnostic and Statistical Manual of Mental Disorders- 5 (Fifth Edition) (DSM-5) (3), ASD is characterised by differences in two main domains: social communication and the presence of restricted and repetitive patterns of behaviour. Sensory difficulties were further acknowledged in the DSM-5 diagnostic criteria for ASD. Previously, under the DSM-IV diagnostic criterion, ASD was classified under the subcategories of, 'Autistic Disorder', 'Asperger's Syndrome' (AS) and ‘Pervasive Development Disorder- Not Otherwise Specified (PDD-NOS) (4). Due to inconsistencies in autism diagnosis, the previous autism diagnostic subcategories were replaced in the DSM-5 with a single umbrella category of ASD (3, 5). Despite this classification change, the core characteristics of ASD relating to difficulties in social communication and restricted behaviour remained the same. The previous DSM-IV autism diagnostic criterion is specified as the inclusion criteria of this thesis, accommodating for the autistic adults diagnosed before the DSM-5 was introduced.

Recent meta-analysis of prevalence studies in 2017 revealed an overall estimate of 62 per 10,000 individuals diagnosed with ASD (6). A recent Australian Bureau of Statistics (7) prevalence report recorded an estimated 164,000 autistic individuals in 2015, representing one in 150 Australians and a prevalence increase of 42% from 2012. A larger proportion of males in Australia (4:1 ratio) were diagnosed with ASD, but recent figures suggest this gender gap is slowly decreasing due to increased understanding and identification of ASD in women (7, 8). Overall, 75% of autistic individuals in 2015 were under 25 (7). Factors contributing to the observed cumulative increase of autism diagnosis in Australia include greater awareness of ASD within health professions and the larger Australian community, and increased access to ASD diagnostic services (9).

# Difficulties autistic adults experience in adulthood

Autism can be described as a heterogeneous condition, with each individual presenting varying levels of adaptive functioning (10). Despite improving levels of symptom severity by late adolescence, the majority of autistic individuals experience difficulties in achieving normative levels of adaptive functioning and are dependent on familial and formal support in adulthood (11-13). Existing comorbid developmental, medical or psychiatric conditions in later life significantly elevate the overall mortality odds in autistic individuals 2.56-fold (14). In an Australian study, the main risk factor for increased mortality was poor mental health wellbeing, with increased prevalence of death resulting from suicide and self-harm (15).

Autistic individuals face many challenges in negotiating the difficulties associated with the transition to adulthood, including navigating higher education, employment, independent living, and adult health services (16, 17). Adulthood produces several uncertainties for autistic adults and their family members, given the loss of entitlement of structured education services and support (18), and increasing demands for managing life independently (13, 19). Services for autistic adults especially those without co-occurring intellectual disability consistently decline in adulthood, a juncture often described as a ‘service cliff’ due to the increasing effort required to access autism-specific support (20).

Autistic adults’ challenges in transitioning to adulthood may be further complicated by several contextual shifts, including changes to established routines, decreasing opportunities for maintaining existing friendships and developing new friendships in new environments (21). Navigating these contextual shifts in social relationships can be challenging. This is evident in studies reporting autistic adults who experience significantly lower social participation and quality of life outcomes, resulting in elevated loneliness and social isolation (12, 22). Qualitative reports from autistic adults capture both their desires to engage socially and the challenges experienced with ‘fitting into’ different social environments, possibly due to difficulties understanding and recognising social cues (23).

The social participation challenges autistic adults face may be partly attributed to social emotional difficulties (24). Previous research has found that competence in social emotional skills is a powerful predictor for successful social participation, promoting increased education and employment participation, as well as improved mental wellbeing (25-27). Social emotional skills are critical in everyday social interactions, providing crucial information of others’ mental states, including cues from facial expressions, body language, contextual cues and vocal prosody (28, 29).

Naturally, all of these details inform the appropriate behavioural responses in a given situation (30).

# Social emotional skills of autistic individuals

In non-autistic development, infants begin to demonstrate social emotional skills through spontaneous facial gaze, reacting to happy and sad emotions by four to seven months (31, 32). By age 10, individuals typically achieve emotion recognition abilities comparable to adults, continuing their development in distinguishing emotion subtleties and complexities (33). By adulthood, non-autistic individuals should achieve proficient levels of emotion recognition, including demonstrating the ability to swiftly perceive both the prototypical and subtle emotions of others (34).

A large body of research underpins the consensus that autistic adults experience difficulties in their emotion recognition skills (24, 35). A recent meta-analysis reported a large effect size for increased social emotional difficulties in autistic adults compared to their non-autistic peers (theory of mind [ToM], $g = –1.09$; emotion recognition, $g = –0.80$), suggesting that these difficulties in autism appear to persist into adulthood (36). While social emotional difficulties have been suggested as a hallmark in autism, questions remain as to the magnitude at which these persist later on, given the mixed research findings (35, 37). The conflicting social emotional findings in autism research may be influenced by variability in experimental manipulations (35). For example, some studies demonstrate comparable performance between autistic and non-autistic individuals in basic facial emotion recognition tasks (38), while others reported atypicalities for tasks involving negative (39) or complex emotions (35, 37). Additionally, several studies found no ToM difficulties in autistic individuals (40, 41), whereas others note the inverse, mainly during tasks assessing advanced ToM concepts (42-45).

Several studies reported variation within the autistic group, with a proportion of individuals demonstrating an absence of social emotional atypicalities (45-47). Demographic factors may, in part, explain some variability in social emotional skills in autism (37); for example, both verbal functioning and ASD symptom severity were found to be associated with the social emotional performance of autistic individuals (40, 48). Another study found a significant age correlation with recognising certain emotions, thus, suggesting autistic individuals have a delayed developmental trajectory of social emotional skill development rather than a universal deficit (49).

Collectively, findings suggest autistic individuals have a heterogeneous social emotional profile, disputing the universal social emotional deficit paradigm in autism (37). Social emotional difficulties may be apparent in some autistic individuals (50), while others display subtle atypicalities in unstructured environments (51). A growing body of research further suggest that social emotional difficulties in autism may be underpinned by differences in processing between autistic and non-autistic individuals. While non-autistic individuals are generally characterised as being ‘proficient’ in social emotional skills, they demonstrate difficulties identifying autistic emotions and mental states (52, 53). Information transfer between autistic and non-autistic peers demonstrated less effectiveness compared to a group with autistic peers (54). The mismatch between autistic and non-autistic social emotional processing is often known as the ‘double empathy problem’ (55, 56). Reframing the universal social emotional deficit paradigm to social emotional differences provides important implications for the design of programs supporting the social emotional skills of autistic adults.

# Existing social emotional interventions in autism

Social emotional interventions address the social communication difficulties autistic individuals face by providing strategies for improving ToM or understanding others’ thoughts, beliefs and emotional states (57). This includes interventions encompassing precursor social emotional domains, including explicit teaching of emotion recognition skills. Two main interventions have been utilised specifically for supporting the social emotional skills of autistic individuals: facilitator-mediated and computer-based approaches.

# Facilitator-mediated approaches

Facilitator-mediated social emotional interventions are underpinned by a goal-orientated relationship, providing individualised learning and developmental support within a safe environment (58, 59). Social emotional interventions utilising facilitator-mediated approaches for autistic individuals are commonly conducted in individual or group environments (60-62). Techniques may involve didactic teaching of social ‘rules’ in different social settings, immediate feedback and reinforcement, role-playing and modelling (61). Facilitator-mediated approaches have previously demonstrated benefits in enhancing overall self-confidence and communication skills of autistic adults (63, 64). Within group environments, a recent meta-analysis reported promising evidence for facilitator-mediated approaches in improving the social skills of autistic individuals aged between five and 21, with an overall reported medium effect ($g = 0.51$).

While facilitated-mediated approaches show promising results, these interventions often target multiple domains of social skills, decreasing the time allocated for social emotional learning (65, 66). Additionally, group-based approaches may not be universally appropriate for autistic individuals considering that it can be costly, time consuming, and practically challenging as individuals are required to be in the same geographical location (67). Further research is needed to explore alternative and more efficacious approaches to support the social emotional skills of autistic adults.

# Computer-based approaches

Recent research has explored the utility of computer-based interventions (CBI) in ameliorating the social emotional difficulties of autistic individuals (68, 69). CBIs are delivered on various platforms, including desktop computers presenting interactive videos or pictures (70, 71), iPads (72), in collaborative learning environments (73), Kinect technology (74) and embedded eye tracking (75). Autistic individuals often have an affinity for computer-based activities, with many engaging in computer-based tasks during their free time (76, 77). Computer-based social emotional interventions can be highly structured and presented in a manner aligning with the preferences of autistic adults, capitalising on their ability to systematise information (70) and their preference for visual learning content, including animated presentations or videos (70, 78). Tailoring content to match individual skill levels and including meaningful reward systems can increase motivation and engagement in CBI (69). Indeed, computer-based stimuli are often less intimidating for autistic individuals, lessening the social environmental demands and providing a safe learning environment to practise and learn complex concepts (79). From a resource perspective, the virtual nature of CBI increases accessibility and outreach, reducing or sometimes eliminating many of the environmental barriers associated with face-to-face interventions. CBI may also provide a more cost-effective option for delivering social emotional interventions in autism (80). Generally, technology-based approaches have demonstrated a medium effect ($g = 0.47$) in targeting the skills of autistic individuals—an effect size similar to a meta-analytic review for social skills groups in autism (81). This suggests that CBI shows promising evidence for targeting the social emotional skills of autistic individuals (65, 69).

While CBI demonstrated promising evidence for targeting the social emotional skills of autistic individuals (69, 81), few studies have directly assessed generalisation of acquired skills to everyday environments. A previous meta-analysis examining the effect of CBI for autistic adults concluded that current CBI demonstrated limited evidence for supporting skill generalisation (81). Adopting the serious game framework was suggested as a useful approach for improving the generalisation of skills (82). CBI development underpinned by a serious game framework enables alignment between the intervention objectives and specific needs of the user (83). While there are several serious game frameworks available (83-85), the framework outlined by Whyte, Smyth (82) is the only autism-specific design framework that articulated principles for enhancing the motivational and skill generalisation outcomes. Hence, this present thesis adopted the serious game framework by Whyte, Smyth (82) for further understanding the strategies for improving the generalisation outcomes of social emotional CBI for autistic individuals.

# Evaluation of social emotional interventions

While previous studies yield promising evidence that supports the efficacy of social emotional interventions for autistic individuals, there is a lack of consistent methodology for evaluating these approaches (86, 87). A recent systematic review of outcome measures utilised in this field of research revealed that only seven assessments were consistently utilised in 5% of the studies (88). This led to the conclusion that inconsistency in outcome measures may obstruct comparison between studies, and further prevent understanding of appropriate interventions for autistic individuals. Sensitive measurement frameworks are also crucial for preventing misidentification of the efficacy of interventions (87). Additionally, given the multidimensional nature of social skills, multimodal measurement frameworks aligning with the intervention targets are essential in understanding the true value of social emotional interventions for autistic adults (87, 89).

Although generalisation outcomes are regarded as critically important, there is a lack of consistency in measures for assessing the effects of social emotional CBI in generalising learnt skills to everyday interactions (57, 69). Of the studies available, the best frameworks examined the differential effect of social emotional interventions on the generalisation of outcomes (86). This includes outcomes measuring both the influence of CBI on directly targeted skills and their more far-reaching effect on social emotional skills to real-life social situations. Differentiating different levels of generalisation measures permits a more comprehensive evaluation of the genuine effects of social emotional interventions in improving the everyday functioning of autistic individuals.

This thesis delineates a tripartite system of classifying outcome measures, allowing for combined discussion and evaluation. Delineating a tripartite system for assessing the efficacy of social emotional interventions allows better assessment and evaluation of the degree of generalised learning, or differentiating the levels of skill application to different contexts (86, 90). The system includes close generalisation outcomes assessing the skills targeted within a social emotional intervention, judged in a format similar to that presented within the intervention. Second, measures of distant generalisation assessed targeted skills in a format substantially different to that presented in the intervention, most typically incorporating more ecologically valid stimuli reflecting naturalistic environments. Figure 1.1 provides an example of both the close and distant generalisation assessments used in a previous study evaluating the efficacy of Mind Reading (70), a CBI containing a series of activities utilising videos of facial expressions. The close generalisation assessment presented stimuli of sample expressions shown against a white background closely reflecting the learning tasks presented within the Mind Reading software. In contrast, the distant generalisation measure presented stimuli cut from feature films, incorporating social interactions in a naturalistic context. Finally, transferability measurements evaluated the effect of social emotional interventions in transferring to non-targeted domains (86), including outcomes relating to autism symptomatology and global changes in social behaviour (91, 92).


**Figure 1.1. Examples of close and distant generalisation outcome measures used in a previous study evaluating the Mind Reading software.**

Source: Golan et al. (44), Golan and Baron-Cohen (62), Golan et al. (80).

A paucity of research has evaluated the efficacy of social emotional interventions for improving the generalisation of skills in this context, possibly due to the lack of standardised measures for assessing social emotional generalisation (57, 69). Due to the lack of generalisation measures available, the present thesis focused on investigating appropriate distant generalisation assessments. Evaluating the effect of social emotional interventions in improving distant generalisation skills is arguably critically important (93), considering that it is likely to reflect genuine improvements of targeted skills to beyond the intervention context.

Increasingly, studies are exploring the utility of more naturalistic assessments incorporating videos of social interactions, in an attempt to understand their effect on more distal social emotional skills (43, 94). To date, there are six published, ecologically valid assessments specifically investigating the social emotional skills of autistic adolescents and adults. Table 1.1 presents a summary of these assessments. Most of these ecologically valid assessments demonstrate good convergent validity and sensitivity in distinguishing autistic and non-autistic adolescents and adults, with the autistic group exhibiting lower social emotional accuracy when viewing naturalistic social scenes. Existing ecological valid assessments draw footage from either television series or feature movies (70, 95, 96), with the exception of three outcome measures taken from customised scripts and footage (43, 94, 97). The latter are regarded as more ecologically valid considering they are purposefully designed to minimise distractions, over-dramatisation of interactions and other character-specific differences (94).

**Table 1.1. Ecologically valid assessments for social emotional processing in autistic individuals**

| Author (Year) | Participants | | | | Test | Stimuli | Social emotional accuracy findings | Psychometric properties |
|---|---|---|---|---|---|---|---|---|
| | Autism | | Non-autistic | | | | | |
| | *n* (male/ female) | Mean age (SD) | *n* (male/ female) | Mean age (SD) | | | | |
| Barnes et al. (95) | 28 (14/14) | 30.29 (7.78) | 28 (14/14) | 30.21 (6.98) | Moral Dilemmas Film Task | Four video clips from the television show *House*, featuring two interacting characters in each clip. Video clips ranged from 30 seconds to two minutes in length. Participants were given five minutes to describe in writing the happenings of the video clip. | • Autistic < non-autistic on length of narratives ($p < 0.01$) and mental states to film characters ($p = 0.01$).<br>• Autistic individuals had greater bias towards describing objects ($p = 0.01$).<br>• Autistic = non-autistic on demonstrating complex mentalising abilities ($p = 0.09$). | • Inter-rater reliability: ICC = 0.93–1.0.<br>• Second-order ToM: Cohen's k reliability = 0.86.<br>• Within the autistic group, verbal IQ correlated with increased mental state terms ($r = 0.500$, $p = 0.01$), and number of characters attributed to mental states ($r = 0.56$, $p < 0.01$).<br>• No significant correlation between EQ and number of mental state terms ($r = -0.01$, $p = 0.98$) in the autistic group. |
| Golan et al. (50) | 22 (17/5) | 29.0 (9.8) | 22 (18/4) | 25.4 (9.6) | Reading the Mind in Films Task | Twenty two video clips taken from feature films. Four forced, multi-choice questions targeted complex emotion recognition. A specific character identified prior to watching was chosen on whom | • Autistic < non-autistic in recognising complex emotions ($p < 0.01$). | • Discriminant validity: 90.9% accuracy in classifying autistic and non-autistic adults.<br>• Verbal IQ positively correlated with task scores ($r = 0.48$, $p < 0.01$). |

| Author (Year) | Participants | | | | Test | Stimuli | Social emotional accuracy findings | Psychometric properties |
|---|---|---|---|---|---|---|---|---|
| | Autism | | Non-autistic | | | | | |
| | *n* (male/ female) | Mean age (SD) | *n* (male/ female) | Mean age (SD) | | | | |
| | | | | | | participants judged their mental state. | | • Task scores negatively correlated with AQ scores ($r = –0.51$, $p < 0.01$).<br>• Task scores positively correlated with facial emotions ($r = 0.63$, $p < 0.01$) and vocal prosody ($r = 0.62$, $p < 0.01$). |
| Heavey et al. (96) | 16 (15/1) | 34.7 (9.5) | 15 (15/0) | 30.7 (8.1) | The Awkward Moments Test | Eight video clips from feature films or local advertisements. Each film was preceded with a mental state and a control question. Participants had to identify the emotion of the chosen character at the end of the scene. | • Autistic < non-autistic on recognising mental state ($p < 0.01$).<br>• No differences in response for time observed between groups.<br>• Autistic < non-autistic on understanding characters' intentions ($p < 0.01$). | • Inter-rater reliability: ICC = 0.99.<br>• IQ not significantly correlated with ToM measures in the autistic group.<br>• Autistic performance on the task was not significantly correlated with the SST ($r = 0.48$). |
| Mathersul et al. (43) | 40 (31/9) | 37.2 (16.2) | 33 (24/9) | 41.7 (17.2) | The Awareness of Social Inference Test | Test contained three subtests. Subtest 1 assessed basic emotion perception, and Subtests 2 and 3 targeted complex emotions and ToM. Subtest 2 | • Autistic < non-autistic on accurately distinguishing sincerity and sarcasm ($p = 0.01$).<br>• Autistic < non-autistic on accurately depicting sarcasm | • Test–retest reliability: 0.74–0.88.<br>• Construct validity: Positively correlated with second-order ToM measures ($r = 0.68$) and emotion perception ($r = 0.45$). |

| Author (Year) | Participants | | | | Test | Stimuli | Social emotional accuracy findings | Psychometric properties |
|---|---|---|---|---|---|---|---|---|
| | Autism | | Non-autistic | | | | | |
| | *n* (male/ female) | Mean age (SD) | *n* (male/ female) | Mean age (SD) | | | | |
| | | | | | | (sincere/indirect) contains 15 video clips of an ambiguous interaction between two characters. Subtest 3 (sarcasm/lies/deception) contains 16 video clips of indirect conversations. | versus deception ($p < 0.01$). | • Cognitive empathy on EQ measure was a significant contributor for the 'think' ($p = 0.02$), 'do' ($p = 0.05$) and 'say' ($p = 0.04$) probes. |
| Müller et al. (97) | 33 (27/6) | 15.6 (1.9) | 23 (14/9) | 16.3 (2.4) | Movie for the Assessment of Social Cognition | A 15-minute video presenting four characters conversing at a dinner party. The video is paused at 43 different time points, whereby participants responded to four multi-choice questions relating to the characters' mental state. | • Autistic < non-autistic on recognising mental state ($p < 0.01$).<br>• No significant group differences in fixation duration towards the eyes ($p = 0.22$).<br>• Autistic < non-autistic on pupil dilation ($p = 0.02$). | • Internal consistency: Cronbach's alpha = 0.84.<br>• Split-half reliability ($r = 0.74$, $p < 0.01$).<br>• Convergent validity significantly correlated with RMET ($r = 0.51$, $p <$ 0. 01), SRS ($r = –0.49$, $p < 0.01$) and EQ ($r = 0.53$, $p = 0.01$).<br>• Discriminant validity: No significant associations with IQ ($r = 0.24$, $p = 0.07$) and age ($r = 0.18$, $p = 0.19$). No correlations with ADOS ($r = 0.15$, $p = 0.39$) and ADI ($r = 0.04$, $p = 0.83$). |

| Author (Year) | Participants | | | | Test | Stimuli | Social emotional accuracy findings | Psychometric properties |
|---|---|---|---|---|---|---|---|---|
| | Autism | | Non-autistic | | | | | |
| | *n* (male/ female) | Mean age (SD) | *n* (male/ female) | Mean age (SD) | | | | |
| Murray et al. (94) | 20 (20/0) | 30.60 (6.52) | 20 (19/1) | 30.65 (6.27) | Strange Stories Films Task | Twelve experimental films and three control clips relating to scenarios to assess intention attribution. Task contains three questions assessing intention, interaction and memory. Questions refer to the last speaking character and final utterance of the film clip. | • Autistic < non-autistic on intention accuracy ($p < 0.01$) and interaction ($p < 0.01$).<br>• Autistic = non-autistic on mental state language scores ($p = 0.13$) and memory questions ($p = 0.14$). | • Convergent validity: Intention scores correlated with SST ($r = 0.61$, $p = 0.01$). No significant correlation on mental state language scores and SST ($r < 0.40$). Intention accuracy was not correlated with RMET ($r < 0.40$).<br>• No significant associations between intention accuracy or interaction scores on ADI-R reciprocal interaction and communication ($r < 0.40$) and AQ scores ($r < 0.40$) in the autistic group.<br>• Intention mental state language was marginally significantly negatively correlated with ADIR-R communication domain ($r = –0.47$, $p = 0.05$). |

ADIR-R: Autism Diagnostic Interview (Revised); ADOS: Autism Diagnostic Observation Schedule; AQ: Autism Quotient; EQ: Empathy Quotient; ICC: intra-class coefficient; IQ: Intelligence Quotient; RMET: Reading the Mind in Eyes Test; SRS: Social Responsiveness Scale; SST: Strange Stories Test; ToM: Theory of Mind.

# Limitations of current social emotional interventions

## Paucity of interventions targeting autistic adults

Although existing social emotional interventions demonstrate promise, a paucity of research has evaluated the efficacy of these approaches with autistic adults. A recent meta-analysis examining the value of social emotional interventions found that only 9% (two of 22 studies) included autistic adults aged 18 and above (57). The paucity of interventions targeting adults suggests there is inadequate understanding of the most appropriate approaches addressing autistic adults' social emotional skills (98, 99). Given that diagnostic trends over recent decades has seen an unprecedented number of young people entering adulthood with an ASD diagnosis, there is a clear need for interventions that are age appropriate and specifically address the needs of autistic adults (100).

## Inconsistent social emotional measurement frameworks

While understanding the effect of social emotional CBI on everyday social skills is clearly important for judging their efficacy (65), there is limited research examining their ability to influence outcomes (69). The efficacy of these interventions can only be understood by employing carefully constructed measurement frameworks that assess both close and distant outcomes (70). At present, only two studies have assessed both close and distant generalisation efficacy of social emotional CBI (70, 90), while a large majority only focus on close generalisation outcomes (71, 101, 102). Studies judging both close and distant outcomes reported inconsistent results between measures (70, 90). Specifically, while CBI significantly improved the close generalisation skills of autistic individuals, no concomitant improvement was observed in distant generalisation social emotional skills. Given these inconsistencies, measurement frameworks assessing the two are crucial for evaluating the genuine effect of social emotional interventions in generalising learnt skills to real-world social interactions.

There is equally limited understanding on the acceptability of social emotional CBI, considering the paucity of evaluation studies investigating the experiences of autistic adults during these interventions (103). Existing studies adopt superficial qualitative methods for examining the efficacy of social emotional CBI, mainly reporting overall satisfaction levels (86, 104) or listing the most enjoyable activities within the intervention (105). Taken together, the paucity of both quantitative and qualitative measures may impede understanding of social emotional CBI in generating meaningful outcomes for autistic adults in their everyday social interactions.

## Varied intervention delivery

Despite the exponential increase in social emotional CBI for autistic individuals over the years (68), a variety of intervention methods have been implemented, limiting direct comparisons between studies. Some CBIs are combined with facilitator-mediated approaches, including receiving support from a tutor (70, 106) or integration into group programs (91, 107). Most existing social emotional CBIs, with or without facilitator-mediated approaches, have been compared to an inactive control group; hence, the relative efficacy between these and computer-based modalities in targeting the social emotional skills of autistic adults remains unclear. To date, only two studies have explored the utility of combining both approaches to enhance social emotional outcomes, and directly compared this to a social skills group (70, 91). Results demonstrate promising evidence of combining facilitator- and computer-based approaches, with greater improvements observed when merging the both approaches in distant social emotional outcomes. Further research is warranted to understand their utility for improving in autistic adults the generalisation of social emotional skills to naturalistic environments.

## Limited engagement in computer-based interventions

Although there is evidence that autistic individuals enjoy computer-based approaches, significant attrition and compliance have been observed in response to some CBIs (70, 76, 108). This indicates that only cursory attention has been paid to strategies aiming to engage and sustain the interest of autistic individuals. Currently available CBI targeting the social emotional skills of autistic adults have largely relied on rote learning approaches for training emotions, including rewarding participants for correctly identifying emotions in stimuli presenting static or dynamic faces (70, 109). This approach may not be universally appropriate for autistic adults given its simplicity—and possibly influencing their motivation to persist with the intervention. Recent advancements in CBI have incorporated features likely to improve the motivational value of learning content, including applying learnt skills to simulated real-life environments (110), and incorporating motivating narratives (107) or interactive games (78). Further studies investigating the most salient features for improving engagement levels of autistic adults in social emotional interventions are required.

# Aim of the thesis

Given that emerging literature recommends using both facilitator-mediated and computer-based approaches for improving the generalisation of social emotional skills (69), the overarching aim of this thesis was to develop a facilitator-mediated social emotional program paired with a CBI, and evaluate the feasibility of these two approaches in targeting individuals' social emotional skills. The thesis addresses gaps in the literature by first investigating age-appropriate social emotional content for autistic adults, specifically factors for improving the engagement and generalisation of skills. Additionally, the second objective was to develop a suitable measurement framework for evaluating the efficacy of social emotional interventions in facilitating the generalised learning of autistic adults to naturalistic social environments.

## Thesis structure

Developing interventions encompasses multiple complex interacting components, including issues in methodology, standardisation, practicality and applicability to the broader population (111). Given the complexities of intervention development, the Medical Research Council (MRC) framework (111) was adopted in this project and provided a structured process for guiding the development of a social emotional program for autistic adults. The MRC framework outlines four phases for intervention development and evaluation; development, feasibility, evaluation and implementation. Given that the novel social emotional program was in the initial development phase, the first two phases outlined in the MRC framework are discussed in this thesis. The elements outlined in the development and feasibility phases are shown in Figure 1.2.

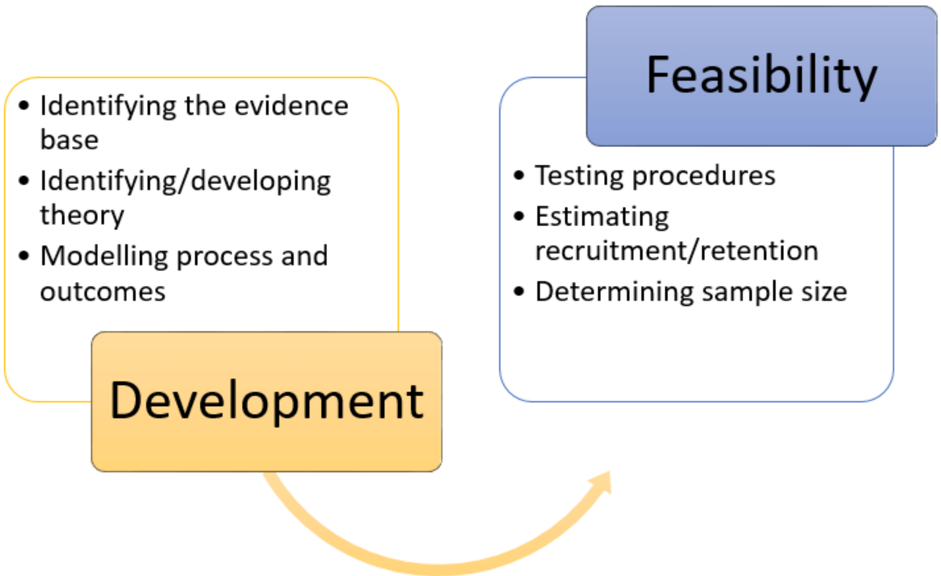


**Figure 1.2. Elements outlined in the development and feasibility phases of the MRC framework.**

Source: Craig et al. (100).

The thesis has two traditional chapters. Chapter 1 provides an introduction and Chapter 8 discusses and concludes the findings. The middle sections of the thesis constitute one bridging chapter and five individual studies presented as peer-reviewed journal manuscripts; these explore the three phases of the thesis, scoping the problem, development and feasibility. Figure 1.3 provides an overview of the overall thesis structure. Various methods were adopted to address the thesis objectives, as presented in Table 1.2.

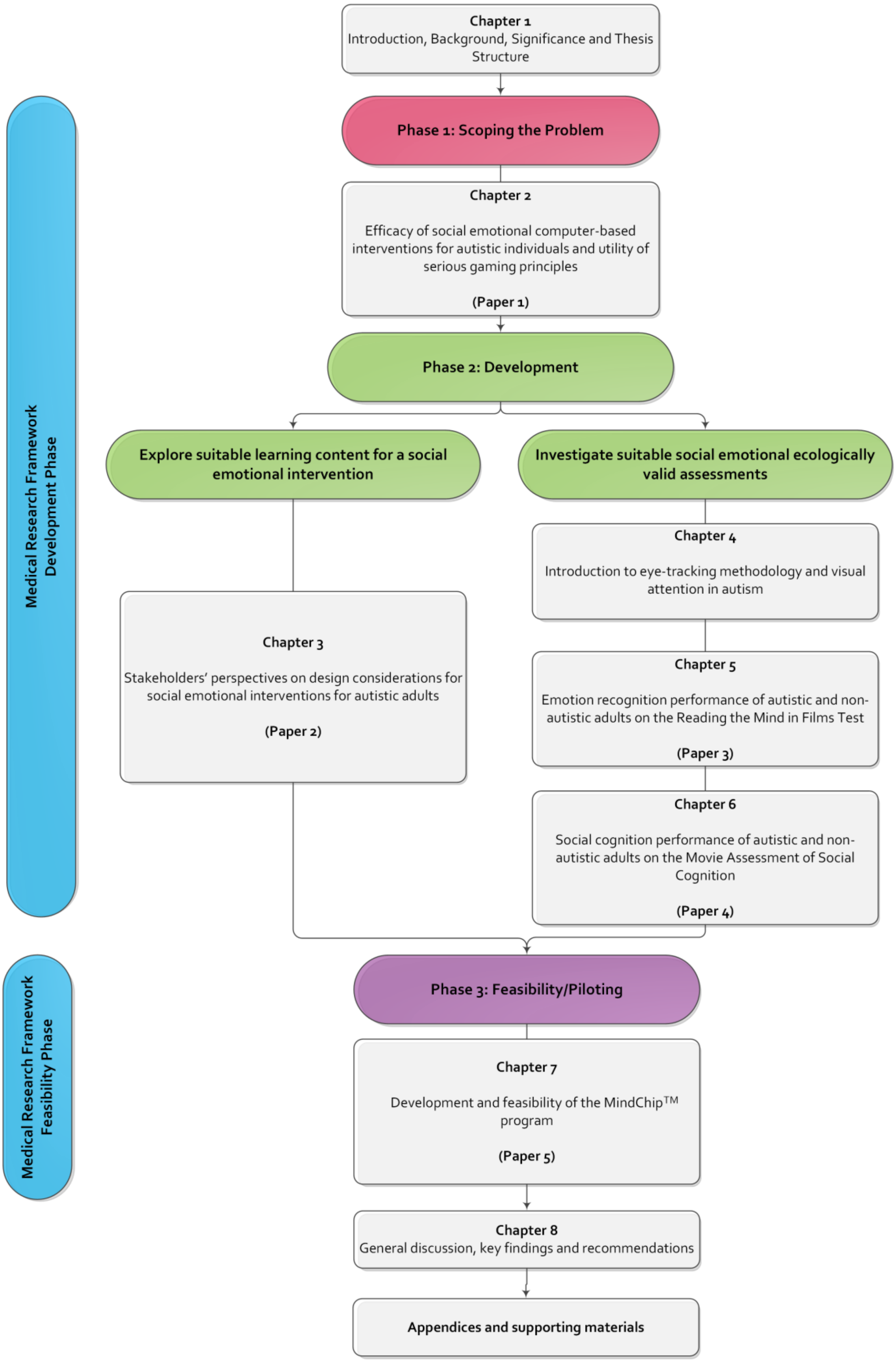


**Figure 1.3. Overall structure of the thesis project.**

# Phase 1: Scoping the problem

Phase 1 of this thesis constitutes a systematic review and meta-analysis that aims to review the existing evidence and identify the active mechanisms driving social emotional intervention efficacy. The results are discussed in detail in Chapter 2. These aim to:

- review the literature pertaining to social emotional CBI for autistic individuals
- systematically evaluate the effect of serious game design principles on remediating the social emotional difficulties of autistic individuals.

This review introduced the use of serious game design principles (82) as a framework for improving the development of CBIs for autistic individuals. Chapter 2 provides a contemporary review of the design quality of CBIs specifically targeting social emotional skills. A meta-analysis evaluated the moderating influence of integrating serious game principles to improve the generalisation of individuals' acquired skills across settings beyond the intervention environment. This paper contributes to the overall thesis by operationalising the serious game framework, examining the effect of serious game design in enhancing the effect of such CBIs for autistic individuals, and by highlighting the importance of considering close and distant outcome measures.

Paper 1: Published in Research in Autism Spectrum Disorders; **impact factor 2.907.**

Tang, J. S. Y., Chen, N. T. M., Falkmer, M., Bölte, S., & Girdler, S. (2019). A systematic review and meta-analysis of social emotional computer based interventions for autistic individuals using the serious game framework. *Research in Autism Spectrum Disorders*, Advance online publication. https://doi.org/10.1016/j.rasd.2019.101412

# Phase 2: Development

Phase 2 described the development process guided by the MRC framework (111), exploring two objectives. The first aimed to explore the fundamental social emotional content specifically for autistic adults, utilising community consultation methods. This included a focus group study (Chapter 3, Paper 2) aiming to obtain stakeholder perspectives on suitable design features and content for a potential social emotional intervention. Views of autistic youth, health professionals and educators were sought and outlined based on the serious game framework (82). Paper 2 contributes to the overall thesis by understanding the key features in social emotional interventions for autistic adults through a community consultation approach, enabling alignment between the intervention features with the preferences and priorities of the autistic community.

Paper 2: Published in Journal of Autism and Developmental Disorders; **impact factor 2.786.**

Tang, J. S. Y., Falkmer, M., Chen, N. T. M., Bölte, S., & Girdler, S. (2018). Designing a serious game for youth with ASD: Perspectives from end-users and professionals. Journal of Autism and Developmental Disorders, 49(3), 978-995. https://doi.org/10.1007/s10803-018-3801-9

The second objective of Phase 2 was to inform a suitable measurement framework for evaluating the generalisation of social emotional skills in response to an intervention. Given that eye-tracking technologies were discussed as a useful tool for broadening the social emotional assessment paradigm, Chapter 4 first provides an overview of eye-tracking measurements and eye-tracking literature examining the visual social attention of autistic individuals. The subsequent chapters investigate two ecologically valid social emotional assessments, the Reading the Mind in Films Test (RMFT) (Chapter 5, Paper 3) and the Movie for the Assessment of Social Cognition (MASC) instrument (Chapter 6, Paper 4) using case control methodology. The objectives of these studies were to:

- compare the performance accuracy of autistic and non-autistic adults in recognising the complex emotional concepts presented in social scenes
- compare, using an eye-tracking methodology, the visual processing mechanisms of autistic and non-autistic adults in recognising complex emotional concepts presented in social scenes.

The first case control study (Chapter 5, Paper 3) introduced the first ecological social emotional assessment, the RMFT, as a potential outcome measure for assessing the emotion recognition skills of autistic adults. Chapter 5 contributes to the overall thesis by determining whether this assessment can distinguish between autistic and non-autistic adults.

Paper 3: Published in Journal of Autism and Developmental Disorders; **impact factor 2.786.**

Tang, J. S. Y., Chen, N. T. M., Falkmer, M., Bölte, S., & Girdler, S. (2019). Atypical visual processing but comparable levels of emotion recognition in adults with autism during the processing of social scenes. Journal of Autism and Developmental Disorders, 49(10), 4009-4018. https://doi.org/10.1007/s10803-019-04104-y

Given that the results reported in Chapter 5 reveal that the RMFT did not to distinguish between autistic and non-autistic adults, a second case control study (Chapter 6, Paper 4) introduced a second ecologically valid outcome measure, known as MASC. This chapter contributes to the overall thesis by confirming its ability to distinguish between autistic and non-autistic adults, suggesting MASC as a more suitable distant generalisation outcome measure for evaluating social emotional interventions.

Paper 4: Manuscript submitted for publication.

Tang, J. S. Y., Chen, N. T. M., Falkmer, M., Bölte, S., Black, M. H. & Girdler, S. (2020). Naturalistic social cognition performance and visual scanning in autistic adults. Manuscript submitted for publication.

# Phase 3: Feasibility

Phase 3 (Chapter 7, Paper 5) describes the development process and feasibility evaluation of a facilitator-mediated social emotional program for autistic adults. Known as MindChipTM, this program was developed for implementation in parallel with an existing emotion recognition CBI, the Mind Reading program. Chapter 7 first summarises the results obtained from Phase 2 (Chapters 3 to 6) of this thesis and discusses the four theoretical underpinnings of the MindChip program: self-efficacy (102), self-management (103, 104), social development theories (105) and person-centred practice (106). Piloting of the MindChip program was undertaken to evaluate its feasibility and acceptability in addressing the social emotional skills of autistic adults. Results include suggestions for improving the MindChip program and CBIs targeting autistic adults. Paper 5 contributes to the thesis by describing the development process of MindChip, and provides outlined suggestions for its improvement.

Paper 5: Manuscript accepted for publication with minor revisions in Journal of Autism and Developmental Disorders; **impact factor 2.786.**

Tang, J. S. Y., Falkmer, M., Chen, N. T. M., Bölte, S., & Girdler, S. (2020). Development and feasibility of MindChip$^{TM}$: A social emotional telehealth intervention for autistic adults. Journal of Autism and Developmental Disorders. Advance online publication. https://doi.org/10.1007/s10803-020-04592-3

# General discussion

Chapter 8 provides a general discussion that synthesises and summarises the research findings. Included in the chapter is a critical review of the contributions, limitations and recommendations for future research. The chapter contributes to the overall thesis by discussing the effect of utilising an individualised approach to improve the generalisation of social emotional skills among autistic adults.

**Table 1.2. Summary of research methods in individual journal manuscripts**

| Aspect | Paper 1 | Paper 2 | Paper 3 | Paper 4 | Paper 5 |
|---|---|---|---|---|---|
| Design | Systematic review and meta-analysis. | Focus group design. | Case control study. | Case control study. | Development and pilot study. |
| Description | Systematic review describing and implementing serious game principles in existing social emotional CBI in autism. | Exploration of stakeholders' perspectives on suitable design features of a social emotional intervention for autistic youth. | Compare the emotion recognition, and behavioural and perceptual performance of autistic and non-autistic adults using the RMFT. | Compare the emotion recognition, and behavioural and perceptual performance of autistic and non-autistic adults using MASC. | Described the development and piloting of the MindChip intervention. |
| Sample | *k* = 34 experimental studies evaluating social emotional CBIs for autistic individuals; *k* = 18 control experimental studies retrieved for meta-analysis. | Autistic youth, *n* = 11; health professionals and educators, *n* = 11. | Autistic adults, *n* = 23; non-autistic adults, *n* = 25. | Autistic adults, *n* = 25; non-autistic adults, *n* = 25. | Autistic adults, *n* = 25, randomly allocated to (1) MindChip and CBI group (*n* = 11) and (2) CBI only group (*n* = 14). |
| Data analysis | Narrative synthesis of serious game design features and meta-analysis. | Content and framework analysis. | Independent *t*-test, Chi squared test, one-way and repeated measures ANOVA. | Kolmogorov–Smirnov test, Mann–Whitney U test, independent *t*-test, Chi-squared test, one-way and repeated measures ANOVA, Pearson's and Spearman's correlation, ROC Analysis | Kolmogorov–Smirnov test, independent *t*-tests, Chi-squared test, repeated measures ANOVA, content analysis. |

ANOVA: analysis of variance; CBI: computer-based intervention; MASC: Movie for the Assessment of Social Cognition; RMFT: Reading the Mind in Films Test; ROC: Receiver operating characteristic.

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# Chapter 2 : Efficacy of social emotional computer-based interventions for autistic individuals and the utility of serious gaming principles

This chapter presents a manuscript that has been published in Research in Autism Spectrum Disorders, **impact factor 2.907:**

**Tang, J. S. Y.**, Chen, N. T. M., Falkmer, M., Bölte, S., & Girdler, S. (2019). A systematic review and meta-analysis of social emotional computer based interventions for autistic individuals using the serious game framework. *Research in Autism Spectrum Disorders*, Advance online publication. https://doi.org/10.1016/j.rasd.2019.101412

# Author contribution statement: Chapter 2

As co-authors of the paper entitled, ‘A systematic review and meta-analysis of social emotional computer based interventions for autistic individuals using the serious game framework’, we confirm that Julia Tang has been the principal research and has made the following contributions:

- Conceptualisation and design of the research;
- Data synthesis and analysis
- Writing the manuscript and critical appraisal of the findings; and
- Corresponding author for communication with the journal.

Our contribution to the paper was consistent with the role of supervisors and involved the following contributions:

- Assistance with conceptualisation and design of the research;
- Assistance with analysis and interpretation (inter-rater reliability for the selection of articles); and
- Review and editing of the manuscript

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|---|---|---|
| Signed: | Nigel TM Chen | Date: 28.05.2020 |
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| Signed: | Sven Bölte | Date: 28.05.2020 |
| Signed: | Sonya Girdler | Date: 28.05.2020 |

# Preface

Chapter 2 presents the ‘scoping the problem’ phase of this thesis, aiming to review the existing evidence relating to social emotional interventions and identify the active mechanisms underlying intervention efficacy. Given the promising evidence of CBI for autistic individuals, a systematic review was conducted aiming to synthesise the features of social emotional CBI and examine, via meta-analysis the efficacy of these interventions for autistic individuals. In synthesising the intervention features, the serious game framework by Whyte et al. (2015) was adopted, summarising the five key guiding design principles for improving the engagement and generalisation of learnt skills for autistic individuals. An assessment tool was developed to quantify the application of serious game design into social emotional CBI. To systematically evaluate the differential impact of social emotional CBI on generalising learnt skills, the review delineated a tripartite measurement system of outcomes evaluating close, distant and transferability of skills. Meta-analyses were conducted to examine the potential moderating impact of serious game application in improving CBI efficacy for autistic individuals.

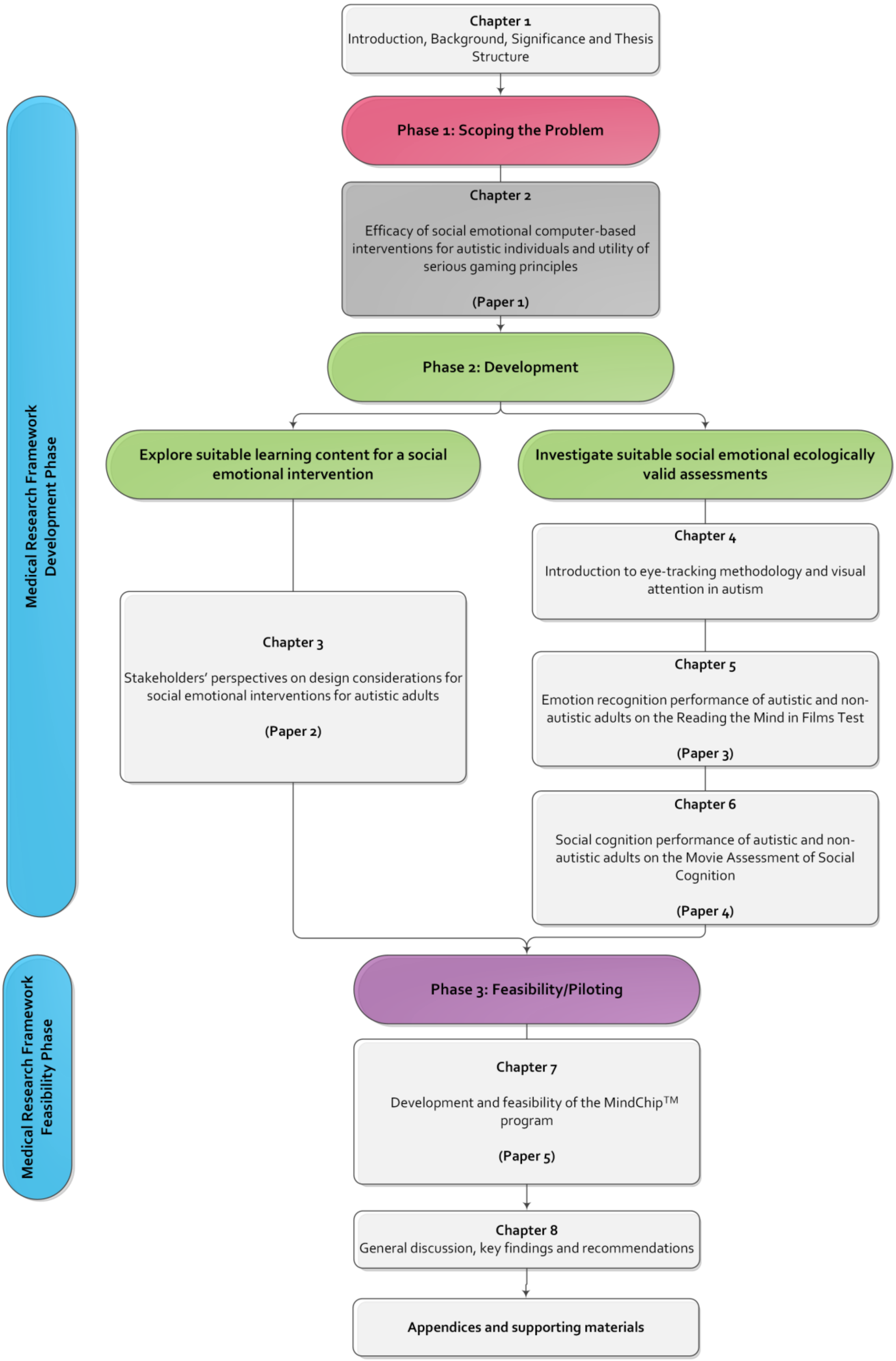


**Figure 2.1. Thesis structure Chapter 2.**

Research in Autism Spectrum Disorders 66 (2019) 101412

Contents lists available at ScienceDirect

Research in Autism Spectrum Disorders

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# A systematic review and meta-analysis of social emotional computer based interventions for autistic individuals using the serious game framework

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ARTICLE INFO

Number of reviews completed is 2

*Keywords:*
Autism
Innovative technology
Social skills
Serious games

ABSTRACT

*Background and aim:* Adopting the elements of the Serious Game framework has been hypothesised as a strategy to promote the efficacy of social emotional computer-based interventions (CBI) for autistic individuals. This systematic review aimed to review the application of Serious Game principles in current social emotional CBI targeting autistic individuals and evaluate the effect of these principles in remediating social emotional outcomes via meta-analysis.
*Methods:* Database searches identified 34 studies evaluating social emotional CBI with 17 controlled efficacy studies included in meta-regressions analyses. Narrative synthesis summarised the attributes of each CBI based on the five Serious Game principles; motivating storyline, goal directed learning, rewards and feedback, increasing levels of difficulty and individualisation.
*Results:* Based on the scores of the Serious Game assessment tool we developed, findings revealed on average a limited (45%) integration of Serious Game design principles in social emotional CBI for autistic individuals. Main findings from the meta-regressions of 17 controlled efficacy studies revealed a moderating effect of Serious Game design principles on the distant generalisation of social emotional skills and transferability of outcomes among autistic individuals. No significant moderating effects of Serious Game was found for close generalisation and maintenance outcomes.
*Conclusion:* Overall, findings suggest that the Serious Game design framework has utility in guiding the development of social emotional CBI which improve the social emotional skills of autistic individuals.

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https://doi.org/10.1016/j.rasd.2019.101412
Received 20 March 2019; Received in revised form 14 June 2019; Accepted 17 June 2019
1750-9467/ 

## 1. Introduction

Difficulties in social communication and interaction is a primary behavioural hallmark of Autism Spectrum Disorder (ASD) (American Psychiatric Association, 2013), contributing to poor social integration and participation outcomes in adulthood (Howlin, Moss, Savage, & Rutter, 2013). Autistic individuals experience lifelong difficulty in developing and maintaining relationships, often requiring assistance to live independently and maintain employment (Levy & Perry, 2011; Magiati, Tay, & Howlin, 2014; Tobin, Drager, & Richardson, 2014). The cumulative impact of ASD is evident in the poor self-reported quality of life (Clark, Magill-Evans, & Koning, 2015; Howlin et al., 2013; Jonsson et al., 2017) and premature mortality of these individuals (Hirvikoski et al., 2016).

Alterations in the social emotional skills of autistic individuals are underpinned by various social cognitive processes such as difficulties in mentalising, joint attention and emotion recognition (Baron-Cohen, 2000; Harms, Martin, & Wallace, 2010; Mathersul, McDonald, & Rushby, 2013; Uljarevic & Hamilton, 2013; Wong & Kasari, 2012). Difficulties integrating essential emotional cues are reportedly another feature characterising ASD (Guillon, Hadjikhani, Baduel, & Rogé, 2014), which become increasingly evident with increasing task demands (Harms et al., 2010). Current approaches aimed at remediating the social emotional skills of autistic individuals commonly occur in highly structured group environments lead by expert clinicians (Turner-Brown, Perry, Dichter, Bodfish, & Penn, 2008; White, Keonig, & Scahill, 2007). Social emotional group interventions are typically framed in line with the typical learning styles of autistic individuals (Baron-Cohen, 2006; Olsson et al., 2017; White et al., 2007), explicitly targeting individual skills through overt instruction, modelling, role-playing and continuous feedback (Reichow, Steiner, & Volkmar, 2012). While these teaching approaches have demonstrated preliminary effect in improving social emotional skills, further evidence is needed before clear conclusions can be drawn in regard to their efficacy (Choque Olsson et al., 2017; Gates, Kang, & Lerner, 2017; Seida et al., 2009; White et al., 2007). However, group approaches may not be universally appropriate for autistic individuals, as they are resource consuming, practically challenging and require participants to be in the same geographical location (Rao, Beidel, & Murray, 2008). Given this context, there is a need to consider additional modalities for teaching fundamental social emotional skills to autistic individuals.

Recent research exploring the utility of computer-based intervention (CBI) in remediating the social emotional skills of autistic individuals (Fletcher-Watson, 2014; Goodwin, 2008) suggests CBI delivered in home environments are both accessible and cost-effective (Goodwin, 2008). Autistic individuals often have a noted affinity for computer based activities (Mazurek, Shattuck, Wagner, & Cooper, 2012; Shane & Albert, 2008), which may provide an opportunity to learn and engage with complex social emotional skills in a safe, structured and predictable environment (Kapp, 2012).

CBI employ a variety of methods aiming to ameliorate the social emotional difficulties of autistic individuals (Fletcher-Watson, 2014), including embedding photographs and videos targeting social skills through repetition (Golan & Baron-Cohen, 2006; Silver & Oakes, 2001), combined with interactive feedback systems informing players of their progress, guiding them through the game (Ramdoss et al., 2012). Some CBI target social emotional skills via narratives ranging in complexity from simplistic themed based games (Faja et al., 2012) to intricate narratives reflecting real life scenarios (Beaumont & Sofronoff, 2008).

Recent years have seen an increase in research evaluating the effects of CBI for autistic individuals (Fletcher-Watson, 2014; Grossard et al., 2017; Grynszpan, Weiss, Perez-Diaz, & Gal, 2014; Ramdoss et al., 2012). At present, there has been one meta-analysis consisting of 14 controlled trials evaluating the overall efficacy of CBI for autistic individuals (Grynszpan et al., 2014). This meta-analysis, including nine studies focusing specifically on remediating social emotional skills, revealed promising evidence supporting CBI in improving skills of autistic individuals, reporting an overall medium effect size ($d = 0.47$). Given the proliferation of CBI in the recent years, an updated evaluation of the efficacy of CBI in remediating social emotional skills is timely. While a previous systematic review concluded that CBI showed some promise in remediating social emotional difficulties of autistic individuals (Ramdoss et al., 2012), these effects were primarily limited to improving 'close generalisation' skills, that is skills directly targeted within the CBI and assessed using a similar format to the intervention itself (Golan & Baron-Cohen, 2006; Swettenham, 1996). Conversely, the effects of CBI in improving the 'distant generalisation' of targeted skills, assessed via formats different to the intervention were more limited (Golan & Baron-Cohen, 2006; Ramdoss et al., 2012; Swettenham, 1996). To date, reviews have aggregated the results of close and distant generalisation social emotional outcomes (Grynszpan et al., 2014), failing to consider how interventions may differentially impact on these outcomes. Meta-analytic evaluation would be further beneficial in understanding the efficacy of social emotional CBI in improving the close and distant generalisation outcomes, particularly given that the ultimate goal of CBI is to transfer improvements in skills in everyday functioning (Ramdoss et al., 2012).

The ability of CBI to target social emotional skills largely depends on their capacity to promote player engagement (Catalano, Luccini, & Mortara, 2014). Current evaluation of these interventions have reported issues associated with attrition and compliance (Golan & Baron-Cohen, 2006; Heimann, Nelson, Tjus, & Gillberg, 1995), issues at least partially attributable to the inattention paid to strategies promoting player engagement (Goh, Ang, & Tan, 2008). Motivating tasks maximise the learning outcomes of CBI, being linked with higher levels of compliance (Habgood & Ainsworth, 2011) and social emotional gains (Beaumont & Sofronoff, 2008). A recent literature review of CBI in ASD suggested that personalisation, immediate feedback and realistic game features potentially increased intervention effectiveness (Fletcher-Watson, 2014). However, the authors acknowledged challenges in synthesising the literature resulting from heterogeneity in study design and limited reporting of design processes (Fletcher-Watson, 2014; Grossard et al., 2017). Further research is needed to identify the most salient design features of these interventions.

The Serious Game framework, previously applied in the fields of health and education has been proposed as relevant for developing CBI in ASD (Whyte, Smyth, & Scherf, 2015). Serious Game design frameworks guide the design phase of CBI, providing guidelines for their development and structure, facilitating the usability and playability of interventions for end-users (Rooney, 2012). There are several existing Serious Game frameworks within the field of ASD (Mitgutsch & Alvarado, 2012; Rooney, 2012;

Yusoff, 2010), drawing on pedagogical frameworks to facilitate the learning experience within these games, including the framework described by Yusoff (2010). Yusoff's (2010) framework was applied in a review evaluating the design quality of Serious Games for autistic individuals (Grossard et al., 2017), concluding there was wide variability in the application of Serious Game design principles, with few games emphasising the playability of CBI.

Whyte et al. (2015) articulated a Serious Game framework outlining the features likely to enhance the motivational aspects of CBI, with the aim of maximising learning opportunities in an engaging environment and generalising skills to everyday contexts (Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012; Whyte et al., 2015). The principles of this framework consider the inclusion of immersive narratives, short and long term goals for targeted skills, providing meaningful feedback and rewards, personalisation and graded difficulty of tasks (Whyte et al., 2015). While the current framework articulates the design principles of Serious Games, clearer operational definitions of these principles would support a more consistent approach to CBI development and evaluation. A systematic approach to evaluating the application of the Serious Game design framework would also enable investigation of the relationship between application of these principles and the efficacy of CBI in ASD.

The overarching aim of the present review was to evaluate, via meta-analysis, the potential impact of Serious Game design in enhancing the effect of social emotional CBI in ASD. The present review firstly sought studies evaluating CBI targeting social emotional skills of autistic individuals, providing a narrative synthesis of intervention features, assessing them against the principles of the Serious Game framework (Whyte et al., 2015) with a tool developed specifically for this review. Secondly, this review aimed to retrieve controlled studies evaluating social emotional CBI, systematically examining the potential moderating influence of Serious Game design principles on the effect of these interventions in remediating social emotional difficulties of autistic individuals.

## 2. Methods

### 2.1. Eligibility criteria

The selection of the articles was conducted in two stages. The first stage aimed to locate studies evaluating social emotional CBI for autistic individuals. The inclusion and exclusion criteria for this stage are outlined in Table 1.

Subsequently, studies retrieved in stage one were evaluated to determine eligibility for a meta-analysis. Studies were included in the meta-analysis if they employed a control group based design involving autistic participants. As a strategy to increase homogeneity of CBI included in the meta-analysis, only those intervention focusing on social and behavioural approaches were included with interventions utilising neurophysiological methods of delivery such as neurofeedback training excluded.

### 2.2. Information sources and search strategy

Five electronic databases, CINAHL Plus (EBSCOhost), Embase (Ovid), ERIC (Proquest), Medline (Ovid), PsychInfo (Ovid) and PudMed were used to locate relevant articles. The main keywords search terms were “autism”, “social”, “emotion”, and “computer”, which were combined with relevant subject headings and Boolean operators, as presented in Table 2. Search strategies for each of the database are outlined in Appendix A. The search was limited to articles published from 1990 to 2018, replicating the search strategy of the previous review (Ramdoss et al., 2012). No language restrictions were placed on the searches. The search was conducted on

**Table 1**
Inclusion and exclusion criteria.

| | Inclusion criteria | Exclusion criteria |
|---|---|---|
| Participants of studies | Participants diagnosed with ASD under the Diagnostic Statistical Manual of Mental Disorders 5 (DSM-5) or IV (DSM-IV) (American Psychiatric Association, 2013), International Classification of Diseases 10 (ICD-10) (World Health Organization, 1992) or the older versions. This inclusion accommodated for the adolescents and adults' population as individuals in this age group were mostly diagnosed under the earlier diagnostic classification. Therefore, studies targeting participants with Autistic Disorder, Asperger's Syndrome and Pervasive Developmental Disorder Not Otherwise Specified were included. | Individuals with Rett syndrome as the primary focus were excluded as the symptoms associated with this condition are related to a specific gene mutation. |
| Type of interventions | Studies evaluating the effect of education and therapy interventions targeting social emotional skills delivered via computerised devices as the primary platform. As per a previous review (Ramdoss et al., 2012), social emotional skills were defined as skills for initiating and maintaining social interactions, including several precursors skills to theory of mind, e.g. emotion recognition, joint attention, imitation and social reciprocity. | Excluded interventions with limited interaction between the user and the computerised platform, in that feedback was not adjusted based on user input. Therefore, programs with minimal user input such as DVD programs and video modelling were excluded. Studies involving advanced technology including virtual reality environments and robotics were excluded in order to focus on traditional screen-based computer software. Interventions targeting social skills for vocational training were excluded. |
| Types of studies | Articles were published in English, and were experimental in design, including randomised controlled trials, quasi experimental design, pre and post-test design and case studies. | Grey literature such as dissertations were excluded. |

**Table 2**
Search strategy.

| Search strategy | |
|---|---|
| 1. | (autis* OR Asperger* OR ASD* OR "pervasive development disorder*" OR PDD) |
| 2. | (Soci* OR "social conversation" OR "social interaction" OR "emotion*" OR "face*" or "facial*" OR feeling* OR "expression*" OR "turn taking" OR "eye contact" OR "joint attention" OR "empath*" OR "theory of mind") |
| 3. | (Computer* OR software* OR technolog* OR "computer based" OR "computer assisted" OR "computer game*" OR "video game*" OR "serious game*" OR "simulation game*" OR "online game*" OR "game based learning") |
| 4. | 1 AND 2 AND 3 |
| 5. | Limit to 1990-2018 |

27th and 28th of July 2016 and updated on the 20th of October 2017 and 17th of December 2018.

### *2.3. Data collection and analysis*

#### *2.3.1. Study selection*

Citations from the search results were imported to EndNote referencing manger where duplicates were eliminated. Screening at the title and abstract level was completed by the first author (JT), eliminating articles clearly irrelevant to the aim of this review. Studies primarily focusing on individuals without an ASD diagnosis and/or interventions targeting health behaviours, rather than social emotional skills were excluded. Full text articles were then retrieved and initially assessed by the first author (JT) for inclusion. For inter-rater reliability, 20% of the total search results were randomly selected and reviewed by two additional reviewers (MF and SG) based on the inclusion and exclusion criteria, achieving Cohen's kappa score of $r_k = .86$–.88, indicative of strong agreement between the reviewers (McHugh, 2012). Any disagreements were resolved via discussion.

#### *2.3.2. Data extraction*

According to the guidelines outlined in the Cochrane Handbook for Systematic Reviews (Higgins & Green, 2011), data extraction included; study design, description of participants including total number, mean age, gender and diagnostic information, intervention features relating to targeted skill domain, and outcome measures relating to Serious Game features and social emotional intervention outcomes. Information on social emotional CBI were primarily derived from the journal articles themselves. Where possible, a Google search was employed to retrieve further information from published sources of the game, freely downloadable game content, video demonstrations and author websites. Available information for each game is provided in Appendix B.

### *2.4. Summary measures*

#### *2.4.1. Serious game outcomes*

The level to which the social emotional CBI included in this review applied the Serious Game principles was evaluated using a specifically develop Serious Game Assessment Tool informed by a review by Whyte et al. (2015), delineating five key principles for enhancing the motivation and learning experience of autistic individuals and facilitating the generalisation of skills. The first guiding principle describes narratives as a useful tool into contextualising and supporting immersive learning experiences, allowing for opportunities to interact with characters within the game. The second principle highlights the importance of structuring goals incrementally towards a long term objective. The third principle points to the importance of both feedback and reward systems in players obtaining information on their progress and collecting tangible rewards in sustaining their motivation for continued play. Incrementally increasing the level of difficulty and individualising the level of challenge represent the fourth and fifth Serious Game principles respectively, aiming to minimise player's frustration and ensuring that the game is appropriately pitched.

The Serious Game Assessment tool developed for this review included an ordinal classification system, quantifying the level to which each CBI applied the Serious Game principles. Full incorporation of a principle into the CBI was given the maximum score of two points. One point was given for partial incorporation and no points was given if the principle was absent within the game. Scores for each of the five game design principles were subsequently summed and converted to a percentage score relative to the maximum obtainable score of 10, with higher scores indicative of a greater incorporation of Serious Game principles. Scores of 49% and below, 50–59%, 60–69%, 70–79% and 80% and above, were taken to reflect limited, average, good, strong and very strong application of Serious Game principles, respectively. The final operational definitions and scoring matrix of the Serious Game Assessment Tool are presented in Table 3. Inter-rater reliability was assessed and achieved a kappa agreement score of $r_k = .96$. Further details on the development of the tool are available in Appendix C.

#### *2.4.2. Social emotional outcomes*

Continuous social emotional outcome measures were extracted, including the pre and post means and standard deviations for intervention and control groups for meta-analyses. Social emotional outcomes included assessments of social interactions or precursors of theory of mind skills such as eye contact, joint attention, emotion imitation and face and emotion recognition. These were then categorised into outcomes relating to close generalisation, distant generalisation, transferability to other skills and maintenance or engagement outcomes. Definitions for each outcome are outlined in Table 4.

**Table 3**
Serious game design evaluation- Scoring matrix.

| Serious game principles | Criteria | Classification (points) | Scoring |
|---|---|---|---|
| Storyline | Storyline is focused on achieving a long term goal or an end purpose, is embedded throughout the entire game and the player is able to engage in purposeful interactions with game characters. | Yes (2) | |
| | The game has some storyline OR the player is able to purposefully interact with characters within the game. However, the game does not have a clear long term goal. | Some (1) | |
| | Game includes themed based content without a storyline. | Themed (1) | |
| | No storyline included in the game. Game focuses on explicit training of skills. | None (0) | |
| Goals | Game has a clear long term goal and achieved through short and medium term goals. | Long (2) | |
| | Game has a medium term goal that is achieved through completing short term goals/tasks but does not include a clear long term goal. | Medium (1) | |
| | Game includes smaller, targeted and isolated individual learning goals/tasks. | Short (1) | |
| Rewards and feedback | Game provides a combination of reward and feedback features. | Both (2) | |
| Note: Rewards are defined as features supporting immediate reinforcement. Feedback provides information on player's progress throughout the game. | Game includes reward systems to provide immediate reinforcement such as visual and auditory stimuli or collectables. | Reward (1) | |
| | Game provides feedback on the player's performance to guide the player towards achieving learning goals. | Feedback (1) | |
| | Game does not include reward and/or feedback features. | None (0) | |
| Increasing levels of difficulty | Game occurs in a variety of context/stimuli to achieve learning goals and increases in level of difficulty (e.g. adding more distractors, amount of stimuli, increasing the speed) in a step-wise manner throughout the game and/or has individualised starting points. | Yes (2) | |
| | Game either uses different contexts/stimuli to train skills or increases in level of difficulty. | Some (1) | |
| | Game has a consistent level of difficulty throughout the program. | None (0) | |
| Individualised (individualising the level of difficulty for the player) | Individualisation is auto-generated by the program. The game automatically generates individualised starting points and adapts the level of difficulty based on the player's game performance. | Yes (2) | |
| | Individualisation is external. The player is autonomous in choosing the level of difficulty of game tasks. | Choice (1) | |
| | Individualisation is external. Level of difficulty is adapted based on the facilitator's judgment of the player's progress. | Facilitator (1) | |
| | No evidence of individualisation. | None (0) | |
| Total Serious Game Score (Maximum Score: 10) | | | |

**Table 4**
Social emotional outcomes.

| Social emotional outcome | Definition |
|---|---|
| Close generalisation | Outcomes evaluating the skills targeted by a given CBI under similar conditions to the intervention. |
| Distant generalisation | Measurements of targeted skills in a different assessment context. |
| Transferability | Social emotional skills which were not specifically targeted by the intervention itself. |
| Maintenance | The effect of the CBI to maintain social emotional skills after a certain period of time post-intervention, as measured via follow-up reports. |
| Engagement | Descriptions of the participant's motivation or interest during CBI, including measurements of attrition rates and qualitative reports. |

### *2.5. Assessment of methodological quality and risk of bias*

The methodological quality of the included studies was assessed according to the Standard Quality Assessment Criteria for Quantitative Studies developed by Kmet, Lee, and Cook (2011). The checklist contains 14 questions linked with a scoring system quantifying if the criteria was met (two points), partially met (one point) or not achieved (zero points). The strength of the methodological quality was ranked with > 80% summary scores were ranked as strong, 70–80% as good, 50–70% as adequate and < 50% as limited (Lee, Packer, Tang, & Girdler, 2008).

### *2.6. Meta-analysis procedures*

Studies evaluating social emotional CBI with a controlled group comparison were retrieved for meta-analysis. Social emotional outcomes were analysed with RStudio Version 1.0.143 (RStudio Team, 2016) and existing RStudio meta-analyses packages, metafor, compute.es and MAd (Del Re & Hoyt, 2014; Del Re, 2013; Viechtbauer, 2010). Estimates of effect sizes with a bias correction (Hedges g) was calculated by dividing the mean difference of pre-post assessment outcomes between intervention and control groups with the pooled pre-standard deviation (Morris, 2008). When means and standard deviations were not explicitly reported, F values and t values were extracted to compute Hedges g treatment effects of CBI from outcome measures in treatment and control groups (Borenstein, 2009).

Effect size data were analysed in four separate random effects meta-analyses to investigate the effect of social emotional CBI in improving close and distant generalisation, transferability and maintenance outcomes. Random effects model was selected to account for possible variance within and between studies (Borenstein, Hedges, Higgins, & Rothstein, 2010). Under each outcome of interest, effect sizes and variances within each individual study were aggregated to reduce the number of data entries (Borenstein, Hedges, Higgins, & Rothstein, 2009). Given the correlation between outcomes were not readily available, a correlation coefficient value of 0.5 was set for all studies (Borenstein et al., 2009). Subgroup analyses investigated the effect of CBI in supporting long term close and distant generalisation as well as transferability outcomes.

If there was sufficient range, i.e. the moderator values within a model were varied, meta-regressions were implemented with Serious Game scores for each individual study applied as moderator variable to determine the influence of Serious Game principles on the effect of social emotional CBI. Total intervention duration converted to minutes and mean age of participants were analysed as potential moderator variables. To obtain a more interpretable intercept value, the moderator variables were centred to the average moderator value across the outcomes included in the meta-regression (Del Re, 2015).

Assessment of heterogeneity was assessed using $Chi^2$ statistics. A value of $p < 0.05$ was applied to determine statistical significance (Higgins & Green, 2011). The degree of inconsistency was described with $I^2$ statistics, values of 25%, 50%, and 75% representing low, moderate and high heterogeneity, respectively (Higgins, Thompson, Deeks, & Altman, 2003). In order to assess publication bias, funnel plots followed by an Egger's test were undertaken to determine funnel plot asymmetry (Egger, Smith, Schneider, & Minder, 1997). Each funnel plot illustrates the observed effect size against the standard errors on the y-axis. Visual inspection of the funnel plots were completed for outcomes with a minimum of ten studies, due to the increased likelihood of Type I error in distinguishing real asymmetry for meta-analysis containing less than ten studies (Sterne et al., 2011). If evidence for publication bias emerged, secondary analysis using the trim and fill method outlined by Duval and Tweedie (2000) was completed.

## 3. Results

### 3.1. Study selection

Following removal of duplicates, a total of 5283 articles were identified through searches of electronic databases. A *priori* screening of the title and abstracts retrieved 114 articles for full text evaluation of eligibility. Overall, a total of 81 articles were excluded, resulting in 32 eligible articles. A manual screening of the references of eligible articles and the systematic review (Ramdoss et al., 2012) retrieved one article. A total of 33 articles were selected for the final inclusion in the review. One published article reported two separate trials (Golan & Baron-Cohen, 2006), resulting in a total of 34 experimental trials meeting the inclusion criteria of this review.

Amongst the 34 studies retrieved from the electronic search, 20 studies adopted a control group based design with autistic participants and were evaluated for meta-analysis inclusion. Two studies were excluded from the meta-analyses, one due to incomplete reporting of data (Bölte et al., 2002) and the other evaluated an intervention other than CBI, i.e. computer game with neurofeedback training (Friedrich et al., 2015). Following visual inspection of funnel plots, one study with a small sample size was removed from the meta-analysis due to the potential for publication bias resulting from an overestimation of effect size (Cheng, Luo, Lin, & Yang, 2018). This resulted in a total of 17 studies being eligible for inclusion in the meta-analyses. Fig. 1 presents a flow diagram of the process for selecting articles.

### 3.2. Study characteristics

In total, 868 participants were included in the 34 experimental trials. Of these 34 trials, 15 evaluated the CBI via a randomised controlled design (Beaumont & Sofronoff, 2008; Bölte et al., 2002, 2006; Cheng et al., 2018; Faja et al., 2012; Fletcher-Watson et al., 2015; Fridenson-Hayo et al., 2017; Friedrich et al., 2015; Hopkins et al., 2011; Lopata, Thomeer, Rodgers, Donnelly, & McDonald, 2016; Rice, Wall, Fogel, & Shic, 2015; Russo-Ponsaran, Evans-Smith, Johnson, Russo, & McKown, 2016; Silver & Oakes, 2001; Tanaka et al., 2010; Thomeer et al., 2015). Fifteen experimental studies employed a pre-test-post-test design (Bauminger-Zviely, Eden, Zancanaro, Weiss, & Gal, 2013; Bernardini, Porayska-Pomsta, & Smith, 2014; Bernard-Opitz, Sriram, & Nakhoda-Sapuan, 2001; Bölte et al., 2015; Faja, Aylward, Bernier, & Dawson, 2008; Gordon, Pierce, Bartlett, & Tanaka, 2014; Golan & Baron-Cohen, 2006; Jouen et al., 2017; LaCava, Golan, Baron-Cohen, & Myles, 2007; Malinverni et al., 2017; Serret et al., 2014; Swettenham, 1996; Thomeer et al., 2011; White et al., 2018), and four studies were described as case studies (Jeffries, Crosland, & Miltenberger, 2016; Lacava, Rankin, Mahlios, Cook, & Simpson, 2010; Miller, Wyatt, Casey, & Smith, 2018; Russo-Ponsaran, Evans-Smith, Johnson, & McKown, 2014).

A total of 20 experiments adopted a group controlled design with autistic individuals, with 13 control groups wait-listed or receiving standard care (Beaumont & Sofronoff, 2008; Bölte et al., 2002, 2006; Bölte et al., 2015; Faja et al., 2008; Fletcher-Watson et al., 2015; Fridenson-Hayo et al., 2017; Golan & Baron-Cohen, 2006; Jouen et al., 2017; Russo-Ponsaran et al., 2016; Silver & Oakes,

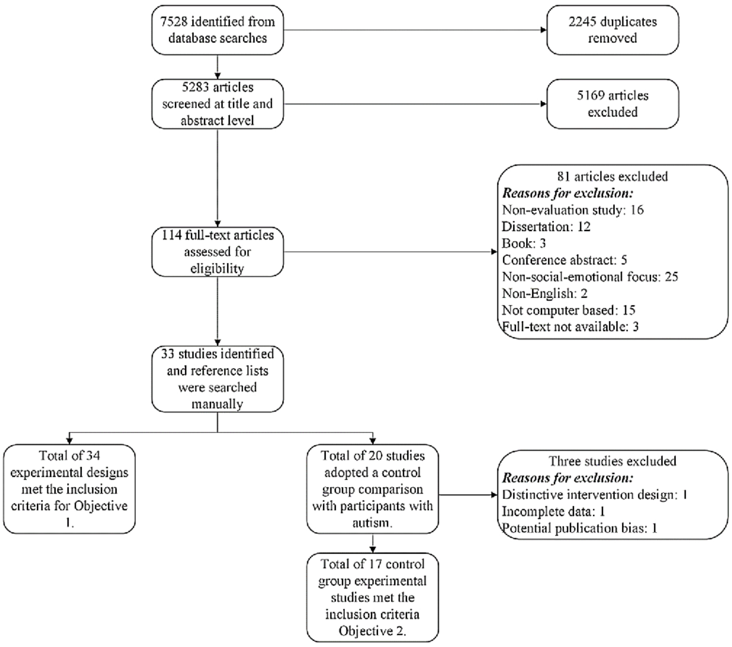


**Fig. 1.** Flow diagram for the selection of articles.

2001; Tanaka et al., 2010; Thomeer et al., 2015), three receiving face-to-face social skills training (Golan & Baron-Cohen, 2006; Lopata et al., 2016; Rice et al., 2015), two groups receiving an intervention without social emotional content (Faja et al., 2012; Hopkins et al., 2011), one study comparing the relative effect of bi-directional versus uni-directional neurofeedback training (Friedrich et al., 2015) and one study using a paper-based emotion recognition training as a control comparison (Cheng et al., 2018). The majority of designs exposed the intervention group to the CBI only, with the exception of three experimental studies which combined CBI with a group therapy program (Beaumont & Sofronoff, 2008; Golan & Baron-Cohen, 2006; Lopata et al., 2016). Details on study designs and group comparison are presented in Table 5.

### 3.3. *Participant characteristics*

#### 3.3.1. *Age and gender*

Participants ranged in chronological age from pre-school aged children to middle-aged adults (ranged 3–52 years), with majority of participants in studies being school-aged children and a smaller percentage (k = 7; 21%) of studies targeting adults. Males comprised the majority of participants, making up 89% of the total sample across studies.

#### 3.3.2. *Sample size*

Sample sizes ranged from 3 to 79 (Jeffries et al., 2016; Russo-Ponsaran et al., 2014; Tanaka et al., 2010). Studies with very small sample sizes typically adopted multiple single-case study designs (Jeffries et al., 2016; Lacava et al., 2010; Miller et al., 2018; Russo-Ponsaran et al., 2014). Larger sample sizes were recruited for studies employing randomised controlled trial designs, with the largest study including 42 participants in the CBI group (Tanaka et al., 2010).

#### 3.3.3. *Diagnosis*

Overall, participants were mainly diagnosed with ASD without an additional intellectual or language impairment, Asperger's syndrome and Pervasive Developmental Disorder Otherwise Not Specified under the DSM-IV, while the remaining were classified under autism or ASD. Twenty studies confirmed diagnosis via validated diagnostic tools such as the Autism Diagnostic Observation Schedule- Generic (Lord et al., 2000), Autism Diagnostic Interview- Revised (Lord, Rutter, & Le Couteur, 1994) or the Childhood Autism Rating Scale (Schopler, Reichier, & Renner, 1986). Nine reported a priori confirmed diagnosis by a clinician supplemented

**Table 5**
Intervention characteristics.

| Author (Year) | Study design | Targeted domain | Intervention | | | | Control group | Methodological quality |
|---|---|---|---|---|---|---|---|---|
| | | | Computer game content | Hardware/ Setting | Computer game duration/ Intensity | Additional components | | |
| Bauminger-Zviely et al. (2013) | Pre-post test | Social collaboration and conversation | Join-In: Participants engaged in themed cooperative activities and collaborated to discuss solutions. No-Problem: Participants were presented with short social conversation vignettes in different social environments. | Hardware: DiamondTouch device and laptop computer Setting: School environment | x12 45 minutes lessons | Guided by facilitators with special education or occupational therapy background. Participants paired with another peer. | NA | Adequate quality (Score = 17/28). Study was limited due to study design, small sample size, limited reporting of analytical methods. Participants differed in ages. Unclear selection strategy. Limited reporting of randomisation method and blinding protocol (blinding of evaluators and participants to intervention condition). |
| Beaumont and Sofronoff (2008) | RCT | Emotion recognition, emotion regulation and social interaction | Secret Agent Society: Game is themed in a futuristic setting. Participants play as a junior detective and undergo three level training program, Level 1: decoding clues from facial expressions, body posture and voice prosody, Level 2: self-regulation and detecting emotions based on situational clues, Level 3: completing missions based on various social conflicts. | Hardware: DVD based application with USB activation. Setting: University laboratory | x4 sessions for computer game (two one hour and two 45 minutes session). | Delivery: Guided by therapists. Sessions are conducted concurrently with parent training. Includes group therapy sessions and 'home missions' with parents. Activities include role-play games, positive reward system with 'tokens', group discussions and feedback Overall, x7 2 hour weekly sessions (time allocated between computer game, parent training and group sessions). | Waitlist | Strong quality (Score = 23/28). Randomisation method was not described. Limited reporting to account for performance bias (blinding of evaluators and participants to intervention condition). |
| Bernardini et al. (2014) | Pre-post test | Joint attention and symbol use (understanding gestures, words, use objects and non-verbal means to in social exchange) | ECHOES: Participants interacts with virtual character named 'Andy' and engages in different activities with 'magic' objects in the sensory garden. | Hardware: Multitouch LCD display with eye tracking. Setting: NA | 10-20 minutes several times per week over a 6 week period. | Participants independently played with the interface with a practitioner supervising in the room (but out of the child's sight). | NA | Poor quality (Score = 9/28). Aim insufficiently described. Limited description of sampling strategy and results, has small sample size and non-randomisation protocol not reported. Limited |

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**Table 5** (*continued*)

| Author (Year) | Study design | Targeted domain | Intervention | | | | Control group | Methodological quality |
|---|---|---|---|---|---|---|---|---|
| | | | Computer game content | Hardware/ Setting | Computer game duration/ Intensity | Additional components | | |
| | | | | | | | | reporting to account for performance bias (blinding of evaluators and participants). Heterogeneous study sample. |
| Bernard-Opitz et al. (2001) | Case-control | Social problem solving | Contains four easy and four difficult social vignettes of conflicts. Participants are prompted by the program to generate solutions to each social conflict. | Hardware: CD-ROM on Windows 95 PCs. Setting: NA | Ten sessions, duration not reported | NA | Typically developing peers | Poor quality (Score = 8/28). Limited in study design. Small sample size. Limited reporting to account for performance bias (blinding of evaluators and participants) and sampling strategy not reported. Participants differed in age and verbal ability. Limited description of results. |
| Bölte et al. (2002) | Pilot RCT | Emotion recognition | Frankfurt Test and Training: Photographs of adult faces and eyes displaying basic emotions. Contains textual information of the emotion and comic strips. | NA | x5 2 hours weekly sessions | NA | No intervention | Poor quality (Score = 8/28). Minimal description of sampling strategy, group characteristics, outcome measurement and results. Randomisation method was not described. Limited reporting to account for performance bias (blinding of evaluators and participants). Small sample size. Inadequate reporting of control of participants' baseline characteristics and results. |
| Bölte et al. (2006) | RCT | Emotion recognition | Frankfurt Test and Training: Same as Bolte et al. (2002). | NA | x5 2 hours weekly sessions | NA | No intervention | Adequate quality (Score = 16/28). Minimal description in inclusion and exclusion criteria. Participants' diagnostic and social skills functioning and matching of |

(continued on next page)

**Table 5** (*continued*)

| Author (Year) | Study design | Targeted domain | Intervention | | | | Control group | Methodological quality |
|---|---|---|---|---|---|---|---|---|
| | | | Computer game content | Hardware/ Setting | Computer game duration/ Intensity | Additional components | | |
| | | | | | | | | baseline characteristics were not reported. Limited reporting to account for performance bias (blinding of evaluators and participants). Small sample size. |
| Bölte et al. (2015) | Quasi | Emotion recognition | Frankfurt Test and Training: Same as Bolte et al. (2002) | NA | x8 1 hour weekly sessions | Assisted by a clinical psychologist. | ASD group received no intervention and typically developing peers. | Adequate quality (Score = 19/28). Randomisation protocol not described. Limited reporting to account for performance bias (blinding of evaluators and participants). |
| Cheng et al. (2018) | RCT | Emotion recognition | 3D Complex Facial Expression Recognition: Contains 3D animated characters and social scenarios, displaying surprise, shy, nervous and embarrassed. Positive textual feedback provided for correct responses. | Hardware: Tablet (Android operating system). Setting: School or home. | x3 40 minutes sessions over 5 weeks. | Educators monitored participant's answers but provided minimal supervision. | Control group received paper-based emotion recognition training. | Adequate quality (Score = 18/28). Randomisation protocol not described. Limited reporting to account for performance bias (blinding of evaluators and participants). Unclear validity of outcome measurement. |
| Faja et al. (2008) | Quasi | Face processing | 24 black and white pictures of male and female faces, either cropped (outer facial features removed) or filtered (distinct details removed). Explicit instruction of configural processing provided. Sessions focused on gender, age and identity matching. Reward image displayed for correct responses. | Hardware: Microsoft PowerPoint and E-Prime software, laptop computer with screen resolution of 1024 × 748 and image resolution of 72 pixels. Setting: NA | x8 30 minutes to 1 hour individual sessions over 3 weeks. | NA | No intervention | Adequate quality (Score = 14/28). Randomisation protocol not reported. Sampling strategy not described. Limited reporting to account for performance bias (blinding of evaluators and participants). Validity and reliability of selected outcome measurement not described. Small sample size. Minimal reporting of results. |

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**Table 5** (*continued*)

| Author (Year) | Study design | Targeted domain | Intervention | | | | Control group | Methodological quality |
|---|---|---|---|---|---|---|---|---|
| | | | Computer game content | Hardware/ Setting | Computer game duration/ Intensity | Additional components | | |
| | | | Presented face picture with the correct label for incorrect responses. Additional pictures are added after each session. | | | | | |
| Faja et al. (2012) | RCT | Face processing | Same as Faja et al. (2008) | Same as Faja et al. (2008) | x8 training sessions | NA | House training: Involved images of houses, structured in a similar format to the intervention. | Good quality (Score = 17/28). Randomisation method was not reported. Limited reporting of blinding protocol (participants and evaluators). Unclear validity and reliability of outcome measurements. Minimal reporting of statistical methods and results. |
| Fletcher-Watson et al. (2015) | RCT | Social communication | FindMe: Joint attention games involving finding a person in various outdoor environments (Part 1) or choosing objects in different shops based on eye or gestural cues (Part 2). Token system with a display of an animation after five tokens were collected. Difficulty increase through increasing the amount of distractors or from displaying gestural to eye cues. | Hardware: iPad application. Setting: Home setting with parents. | Varied. 2 months access to game was provided. Recommended usage was at least 5-10 minutes per day. | All participants received treatment as usual along with computer based intervention. | Waitlist | Strong quality (Score = 24/28). Reporting of participant blinded to intervention condition not described. One assessment was conducted by a blinded assessor. Differences in participant's verbal and non-verbal ability reported. |
| Friedrich et al. (2015) | RCT | Social interactions, imitation and emotional responsiveness | Social Mirroring Game: Participant plays as an avatar completing a treasure hunt mission with another game character. | Hardware: EEG set up recorded using Thought Technology Ltd. Bioamplifiers and proprietary software. Setting: NA | x16 1 hour sessions, 2-3 times per week over 6-10 weeks. | Neurofeedback training to increase mu rhythm during social and non-social episodes. Game includes EEG thresholds which subsequently increases as the | Neurofeedback training to decrease mu rhythm during social and non social episodes. | Adequate quality (Score = 18/28). Sampling strategy and randomisation protocol not reported. Limited reporting of blinding protocol. Small sample size. Minimal |

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**Table 5** (*continued*)

| Author (Year) | Study design | Targeted domain | Intervention | | | | Control group | Methodological quality |
|---|---|---|---|---|---|---|---|---|
| | | | Computer game content | Hardware/ Setting | Computer game duration/ Intensity | Additional components | | |
| | | | Includes social (imitates facial expressions) and non-social gaming tasks. Positive feedback involves avatar successfully imitating the expression of the other character (social tasks) and objects hitting the target (non-social tasks). | | | participant progresses in the game. | | description in results. |
| Friedenson-Hayo et al. (2017) | RCT | Emotion recognition | Emotiplay: Participant plays the role of an explorer in a center researching human behaviour and emotion recognition. Game provided options to personalise avatar and collect items to purchase objects. Participants progress through educational materials from a professor and complete themed based games. | Hardware: Online computer game. Setting: Home | x8 weeks intervention period, at least 2 hours per week. | Parents were provided with an activity guide. | Waitlist | Good quality (Score = 21/28). Randomisation protocol not reported. Limited blinding of participants and evaluators to intervention condition. Insufficient description of the validity and reliability of close generalisation outcome measurements. |
| Golan and Baron-Cohen (2006)-1 | Quasi | Emotion recognition | Mindreading: Contains three gaming areas, (1) Emotion library: A library of videos of facial expressions, voice recordings and situational written examples of the emotion. (2) Learning centre: Quizzes and lessons about emotions. Collectables used as rewards for correct responses. (3) Game zone. | Hardware: CD-ROM or DVD-ROM on an IBM compatible computer. Setting: Home | Total of 20 hours (2 hours/week over 10-14 weeks). | NA | No intervention ASD group and typically developing peers group | Good quality (Score = 21/28). Randomisation protocol not reported. Some (2/3) evaluators were blinded. Blinding of participants to treatment condition was not reported. High attrition rate. |

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**Table 5** (*continued*)

| Author (Year) | Study design | Targeted domain | Intervention | | | | Control group | Methodological quality |
|---|---|---|---|---|---|---|---|---|
| | | | Computer game content | Hardware/ Setting | Computer game duration/ Intensity | Additional components | | |
| Golan and Baron-Cohen (2006)-2 | Quasi | Emotion recognition | Same as Golan & Baron-Cohen (2006) above | Same as Golan and Baron-Cohen (2006) above | x10 sessions (2 hour per week) | Participants attended additional group sessions facilitated by a tutor. Activities include analysis of emotions from real life examples, films or pictures. Group sessions were associated with the computer program. | Social skills group with explicit teaching, group discussions, role plays and analysing emotions from pictures. | Good quality (Score = 20/28). Randomisation not reported. Half of the evaluators were blinded (2/3). Blinding of participants to intervention group not reported. Small sample size. |
| Gordon et al. (2014) | Pre-post test | Emotion imitation | FaceMaze: Participants control a neutral face through a maze and mimics expressions to remove obstacles. Progress bars are filled after each correct responses and participants collects tokens along the maze. | Hardware: Computer Emotion Recognition Toolbox- real life facial expressions analysis. Setting: NA | NA | Real time feedback of emotion expressions based on video webcam analysis. | Typically developing peers | Adequate quality (Score = 15/28). Limited reporting of autism severity and blinding protocol. Small sample size. Heterogeneous study population. |
| Hopkins et al. (2011) | RCT | Joint attention, face and emotion recognition | FaceSay: Animated faces used in three themed games, 'Amazing Gazing', 'Band-Aid Clinic' and 'Follow the Leader'. Response options progressively increases. Player gains points for correct responses. | Hardware: Windows or Apple computers. Touch screen applications available. Setting: School or after school care | x12 10-25 minutes session, twice a week over 6 weeks. | One or two experimenters available to provide assistance. Positive reinforcement and reward was provided if participants demonstrated appropriate behaviour. | TuxPaint, computer based drawing software | Good quality (Score = 22/28). Randomisation method not described. Limited reporting of matching of participants' baseline characteristics. Small sample size. Limited reporting of blinding protocol (participants). Blinding of evaluators not reported, however achieved strong inter-rater reliability scores. |
| Jeffries et al. (2016) | Case studies | Joint attention (eye contact) | Look in My Eyes Steam Train: Participants play as a train engineer. In the training phase, coals are rewarded for correct identification of the number | Hardware: iPad application. Setting: Therapy centre. | NA | Therapist available during session but no prompts were provided. | NA | Poor quality (Score = 7/28). Study design without random allocation. Limited description of sampling strategy, participants' characteristics, analytical method and results. |

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**Table 5** (*continued*)

| Author (Year) | Study design | Targeted domain | Intervention | | | | Control group | Methodological quality |
|---|---|---|---|---|---|---|---|---|
| | | | Computer game content | Hardware/ Setting | Computer game duration/ Intensity | Additional components | | |
| | | | shown on the person's eyes. After four coals are collected, the reward phase is activated (train delivers package to the designated location). | | | | | Blinding of evaluators and participants not reported. Small sample size. Validity and reliability in outcome measurement not reported. |
| Jouen et al. (2017) | Quasi | Imitation and joint attention | GOLIAH: Contains 11 games targeting imitation and joint attention. Activities adapted from the Early Start Denver Model program. Levels of difficulty or goals are allocated by the therapist or parent. Smiley faces and auditory feedback are provided at the end of each game. | Hardware: Microsoft Visual Studio 10 Platform in C# language. Setting: Therapy centre and home. | x5 sessions per week (each session lasts approximately 30 minutes to 1 hour), over 6 months. | Therapist meet with child and parent once per week for one hour for review, planning and intervention (face to face and computer game). | Waitlist | Good quality (Score = 21/28). Limited in study design. Blinding of assessors and participants not reported. Small sample size. |
| LaCava et al. (2007) | Pre-post test | Emotion recognition | Mindreading: Details available in Golan and Baron-Cohen (2006). | Hardware: CD-ROM or DVD-ROM on an IBM compatible computer. Setting: Home or school. | x10 weeks | NA | NA | Adequate quality (Score = 15/28). Minimal description in results. Heterogeneous study population. Small sample size. Absence of control group and limited reporting of blinding protocol. |
| Lacava et al. (2010) | Case studies | Emotion recognition | Mindreading: Details available in Golan and Baron-Cohen (2006). | Hardware: CD-ROM or DVD-ROM on an IBM compatible computer. Setting: School | x7-10 weeks | NA | NA | Poor quality (Score = 10/28). Study design without random allocation. Insufficient reporting of participants' characteristics and results. Autism diagnosis confirmation not reported. Limited reporting to account for performance and detection bias. Small sample size. Heterogeneous study sample. |

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**Table 5** (*continued*)

| Author (Year) | Study design | Targeted domain | Intervention | | | | Control group | Methodological quality |
|---|---|---|---|---|---|---|---|---|
| | | | Computer game content | Hardware/ Setting | Computer game duration/ Intensity | Additional components | | |
| Lopata et al. (2016) | RCT | Emotion recognition | Mindreading: Details available in Golan and Baron-Cohen (2006). | Hardware: CD-ROM or DVD-ROM on an IBM compatible computer. Setting: Summer camp | x3 70 minutes treatment cycles per week over 5 weeks | Participants mainly played the game independently. Each week begins with an introduction of two new emotion groups and the third session focuses on a review of the emotions learnt. Includes a social skills group component with explicit teaching of other social skills. | SummerMAX social skills group (targeted social skills with role-plays, modelling, and feedback). | Strong quality (Score = 26/28). Limited reporting of blinding of participants to the intervention. Small sample size. |
| Malinverni et al. (2017) | Pre-post test | Social initiation | Pico's adventures: Participants engage in missions to initiate a friendship and go on adventures with a virtual character (Pico). | Hardware: Kinect based video game. Setting: Research facility. | One 45 minutes session | Participant played the game independently in the initial level. Involvement of parents and other children is introduced in the subsequent levels. | NA | Poor quality (Score = 7/28). Observational study design. Minimal description of sample characteristics. |
| Miller et al. (2017) | Case studies | Joint attention | Game contains static facial pictures accompanied by a voice recording prompt, 'Look at me'. Audio feedback was provided for eye contact made for five seconds. | Hardware: Computer monitor attached to an infrared camera, tracking the player's eye gaze. Setting: Research centre | Not specified | Participants were accompanied by a researcher who provided additional prompts or reinforcement when required. | NA | Poor quality (Score = 5/24). Weak study design, sample strategy and participant characteristics minimally described. Limited description of outcome measures and analytic methods. Small sample size. |
| Rice et al. (2015) | RCT | Joint attention and face processing | FaceSay: Details available in Hopkins et al. (2011). | Hardware: Windows or Apple computers. Touch screen applications available. Setting: School or after school care | x10 25 minutes session, once per week. | NA | SuccessMaker computer-based courses on language and analytical skills. | Good quality (Score = 21/28). Limited description of autism diagnosis, randomisation method and blinding protocol. Small sample size and participants' baseline characteristics not matched. |

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**Table 5** (*continued*)

| Author (Year) | Study design | Targeted domain | Intervention | | | | Control group | Methodological quality |
|---|---|---|---|---|---|---|---|---|
| | | | Computer game content | Hardware/ Setting | Computer game duration/ Intensity | Additional components | | |
| Russo-Ponsaran et al. (2014) | Case studies | Emotion recognition and self-expression | MiX: Contains videos of seven targeted emotions (happy, sad, angry, fear, surprised, contempt). The speed of the videos can be manually adjusted. Explicit instructions of each emotion is available in the program. | Hardware: Available online via internet browser. Setting: Research Centre. | X16 sessions over 8 weeks (1 hour sessions twice per week) | Facilitator available to provide explicit instructions and feedback of the facial features in each emotions and provide participants with prompt to imitate an emotion. Participants view their facial expressions via webcam. | NA | Poor quality (Score = 13/28). Study design without random allocation. Inadequate description of blinding protocol. Small sample size. Minimal reporting of statistical methods and control for possible confounding factors. |
| Russo-Ponsaran et al. (2016) | RCT | Emotion recognition and self-expression | MiX: Details available in Russo-Ponsaran et al. (2014). | Details available in Russo-Ponsaran et al. (2014). | Details available in Russo-Ponsaran et al. (2014). | Details available in Russo-Ponsaran et al. (2014). | Waitlist | Good quality (Score = 20/28). Independent evaluator was used for one outcome. Possible bias in randomisation method (coin flip), small sample size, incomplete reporting of results, age differences is a possible confounding factor and insufficient reporting of blinding protocol. |
| Serret et al. (2014) | Pre-post test | Emotion recognition | JeStiMulE: Game has a learning phase and a training phase. The learning phase has three levels involving recognition of emotions from avatars based on face only, face with gestures and faces combined with both gestures and verbal content. Training phase is based in a virtual city, embedded with social scenarios with a task to recognise the emotion displayed in each scenario. | NA | Twice a week over 4 weeks (one hour per session) | Includes tactile stimulation on gamepad. | NA | Adequate quality (Score = 18/28). Study design did not include a controlled group. Insufficient reporting of blinding protocol. Heterogeneous study population. Unclear reliability in measurements as it is designed by investigators. Small sample size. |

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**Table 5** (*continued*)

| Author (Year) | Study design | Targeted domain | Intervention | | | | Control group | Methodological quality |
|---|---|---|---|---|---|---|---|---|
| | | | Computer game content | Hardware/ Setting | Computer game duration/ Intensity | Additional components | | |
| Silver and Oakes (2001) | RCT | Emotion recognition and theory of mind | Emotion Trainer: Includes five game tasks each containing photographs of facial expressions, an emotion triggering situation, or mental states tasks. Hints are provided for incorrect responses. Textual positive message and animation followed a correct response. | Hardware: NA Setting: School. | X10 daily 30 minutes sessions over 2-3 weeks | NA | Treatment as usual | Adequate quality (Score = 14/28). Sampling strategy insufficiently described. Autism diagnosis not described and confirmed. Minimal reporting of randomisation and blinding protocol. Small sample size. Unclear validity and reliability of outcome measurements. Insufficient reporting of results. Participants' baseline characteristic not matched. |
| Swettenham (1996) | Case control | Theory of mind | Computerised version of Sally-Anne false belief task. Program provides textual prompts, and immediate positive reinforcement using music and animation. | NA | Two sessions per day over four days. Each session consists of six trials. | NA | Typically developing peers and peers with Down Syndrome | Poor quality (Score = 8/28). Insufficient description of aim, sampling strategy, participants' autism severity, analytical methods and results. Non-random allocation. Limited reporting of blinding protocol. Small sample size. |
| Tanaka et al. (2010) | RCT | Face processing | Let's Face It!: Contains seven themed games. Participants have the option to select the mode and level of difficulty. They had the option to input their scores on the high score website. | Hardware: Program downloadable online and compatible with IBM computers. Setting: Home. | 20 hours (instructed to play at least 100 minutes per week) | Parents are provided with tokens as an incentive to play the game. | Waitlist | Adequate quality (Score = 18/28). Minimal description in randomisation protocol and estimate of variance. Limited reporting of blinding protocol and results. Unclear validity and reliability in selected outcome measurement. |
| Thomeer et al. (2011) | Pre-post test | Emotion recognition | Mindreading: Details available in Golan and Baron-Cohen (2006). | Hardware: CD-ROM or DVD-ROM on an IBM compatible computer. Setting: University computer laboratory. | X12 sessions, two 90 minutes session per week over 6 weeks | Participants practised recognising and displaying emotions with a facilitator. Behaviour reinforcement system was used | NA | Adequate quality (Score = 18/28). Limited in study design as a controlled comparison group not available. Small sample size. Minimal |

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**Table 5** (*continued*)

| Author (Year) | Study design | Targeted domain | Intervention | | | | Control group | Methodological quality |
|---|---|---|---|---|---|---|---|---|
| | | | Computer game content | Hardware/ Setting | Computer game duration/ Intensity | Additional components | | |
| | | | | | | outside of the computer program whereby participants earn points for appropriate social behaviours and correct identification/ expression of emotions. | | description in analytical method. |
| Thomeer et al. (2015) | RCT | Emotion recognition | Mindreading: Details available in Golan and Baron-Cohen (2006). | Hardware: CD-ROM or DVD-ROM on an IBM compatible computer. Setting: University computer laboratory. | X24 sessions, two 90 minutes session per week over 12 weeks | Details available in Thomeer et al. (2011). | Waitlist | Strong quality (Score = 24/28). Limited reporting of blinding protocol. |
| White et al. (2018) | Case control | Emotion recognition | FEET: Contains four levels, consisting of cartoon faces, dynamic videos of real faces, audio recordings and avatars. Prompts are more subtle as they progress through the levels. Visual and audio feedback are provided for correct responses. Players are given the option to reattempt the question after an incorrect response. | Hardware: Kinect sensor attached to a computer. Setting: Research centre. | x1 session 60-90 minutes | Kinect senor capture player's facial expression and provide real time feedback. | NA | Adequate quality (Score = 12/24). Sample strategy not described. Limited description of analytical methods. |

Note: ASD = Autism Spectrum Disorders; EEG = Electroencephalography; LCD = Liquid-crystal display; NA = Not available/applicable; PC = Personal computer; Quasi = Quasi-experimental study; RCT = Randomised Controlled Trial.

with confirmation of autism symptomatology via screening instruments, such as the Childhood Asperger Syndrome Test (Scott, Baron-Cohen, Bolton, & Brayne, 2002), Autism Behaviour Checklist (Krug, Arick, & Almond, 2008), Social Communication Questionnaire (Rutter, Bailey, & Lord, 2003), Social Responsiveness Scale (Constantino & Gruber, 2007) or the Autism Spectrum Quotient (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). In five of the included studies, procedures for verifying ASD diagnosis were not described (Jeffries et al., 2016; Lacava et al., 2010; Miller et al., 2018; Silver & Oakes, 2001; Swettenham, 1996).

#### 3.3.4. *Level of functioning*

The majority of participants were reported to have a verbal and nonverbal intellectual quotient of 70 and above, with a subset of studies (k = 4) including individuals with an intellectual disability (Hopkins et al., 2011; Jouen et al., 2017; Miller et al., 2018; Serret et al., 2014). Table 6 presented the characteristics of participants in the included studies.

### 3.4. *Intervention targets*

As per the inclusion criteria of this review the intervention targets of studies were social skills relating to social emotional outcomes. Data synthesis categorised targeted skills according to social cognitive skills and social skills. Twenty nine studies focused on social cognition skills associated with theory of mind (Swettenham, 1996), face processing (Faja et al., 2008, 2012; Hopkins et al., 2011; Rice et al., 2015; Tanaka et al., 2010), emotion recognition (Beaumont & Sofronoff, 2008; Bölte et al., 2002, 2006; Bölte et al., 2015; Cheng et al., 2018; Fridenson-Hayo et al., 2017; Golan & Baron-Cohen, 2006; Hopkins et al., 2011; LaCava et al., 2007; Lacava et al., 2010; Lopata et al., 2016; Russo-Ponsaran et al., 2016, 2014; Serret et al., 2014; Silver & Oakes, 2001; Thomeer et al., 2011, 2015; White et al., 2007) and joint attention (Bernardini et al., 2014; Fletcher-Watson et al., 2015; Hopkins et al., 2011; Jeffries et al., 2016; Jouen et al., 2017; Malinverni et al., 2017; Miller et al., 2018; Rice et al., 2015). Five experimental studies examined social skills involving collaboration with a partner to generate solutions (Bauminger-Zviely et al., 2013; Malinverni et al., 2017), emotion management (Beaumont & Sofronoff, 2008), problem-solving social conflicts (Bernard-Opitz et al., 2001), imitating and responding to emotions (Friedrich et al., 2015; Gordon et al., 2014), social conversations (Bauminger-Zviely et al., 2013), and social initiation skills (Malinverni et al., 2017).

Across the 34 included articles, a total of 24 different social emotional CBI were evaluated. Eight computer programs were commercially available for purchase; Emotion Trainer (Silver & Oakes, 2001), FaceSay (Hopkins et al., 2011), FindMe (Fletcher-Watson et al., 2015), Let's Face It! (Tanaka et al., 2010), Look in eyes: Steam Train (Jeffries et al., 2016), Mindreading (Golan & Baron-Cohen, 2006), MiX (Russo-Ponsaran et al., 2016), and Secret Agent Society (formerly known as the Junior Detective Training Program) (Beaumont & Sofronoff, 2008). Six computer program, ECHOES (Bernardini et al., 2014), Gaming Open Library for Intervention in Autism at Home (GOLIAH) (Jouen et al., 2017), Join In and No Problem (Bauminger-Zviely et al., 2013), JeStiMule (Serret et al., 2014) and Pico's Adventures (Malinverni et al., 2017) were at the piloting and/or development phase. Several computer programs were integrated with automated detection software enabling participants to manipulate the game using facial movements (Gordon et al., 2014; White et al., 2018), eye movements (Miller et al., 2018) or brain activity (Friedrich et al., 2015). One program integrated the player's image into the gaming environment through Kinect technology (Malinverni et al., 2017). Other programs presented social emotional stimuli such as animated characters (Cheng et al., 2018), photographs (Bölte et al., 2002; Faja et al., 2008) or a series of social vignettes (Bernard-Opitz et al., 2001; Swettenham, 1996). Additional details on the computer based interventions are outlined in Table 5.

### 3.5. *Social emotional assessments*

Raw data from social emotional outcome measurements is available in Appendix D.

#### 3.5.1. *Close generalisation*

A total of 16 studies evaluated close generalisation outcomes using multiple assessment measures relating to social cognitive and social skills outcomes. Social cognitive outcomes targeting face and affect processing were measured in response to a variety of stimuli, including static images, dynamic videos of real life faces or voice recordings in a similar format to the intervention (Beaumont & Sofronoff, 2008; Bölte et al., 2006, 2015; Cheng et al., 2018; Faja et al., 2008, 2012; Fridenson-Hayo et al., 2017; Golan & Baron-Cohen, 2006; Hopkins et al., 2011; Lopata et al., 2016; Rice et al., 2015; Russo-Ponsaran et al., 2016; Silver & Oakes, 2001; Tanaka et al., 2010; Thomeer et al., 2015). Emotion imitation skills were measured in one study via ratings of the emotion expressed by the participant (Russo-Ponsaran et al., 2016). One study evaluated emotion management using an interviewer administered questionnaire eliciting participants' response to a social scenario (Beaumont & Sofronoff, 2008).

#### 3.5.2. *Distant generalisation*

Amongst the 17 included controlled trials, eight studies reported pre and post distant generalisation outcomes (Beaumont & Sofronoff, 2008; Fletcher-Watson et al., 2015; Fridenson-Hayo et al., 2017; Golan & Baron-Cohen, 2006; Lopata et al., 2016; Russo-Ponsaran et al., 2016; Thomeer et al., 2015), assessing emotion recognition, emotion awareness, emotion regulation and social communication skills. Distant generalisation assessments were mainly computer-based (Fridenson-Hayo et al., 2017; Golan & Baron-Cohen, 2006; Russo-Ponsaran et al., 2016) or researcher administered assessments (Lopata et al., 2016; Russo-Ponsaran et al., 2016) scoring participants' accuracy in identifying or interpreting static images, audio recordings or naturalistic social interaction videos. Four studies measured distant generalisation via parental reports (Beaumont & Sofronoff, 2008; Fletcher-Watson et al., 2015; Lopata

**Table 6**
Participants' characteristics.

| Author (Year) | N (male/female) | Mean age* (SD) | | Diagnosis | Comorbidities | Inclusion and exclusion criteria |
|---|---|---|---|---|---|---|
| | | Intervention | Autism control group | | | |
| Bauminger-Zviely et al. (2013) | 22 (18/4) | 9.83 (10.72) | NA | Autistic disorders and ASD, DSM-IV-TR, ADOS & SCQ | NA | Inclusion: WISC-IV performance IQ and PPVT verbal IQ ≥ 70<br>Exclusion: Behaviour difficulties and/or ADHD |
| Beaumont and Sofronoff (2008) | 49 (44/5) | 9.64 (1.21) | 9.81 (1.26) | AS, DSM-IV-TR, CAST | NA | Inclusion: WISC-III IQ ≥ 85 |
| Bernardini et al. (2014) | 19 | 8.42 | NA | ASD, AS, SCQ | NA | Inclusion criteria: Verbal language ability- BPVS M = 36.62. 7/9 participants scored low on BPVS. |
| Bernard-Opitz et al. (2001) | 16 | 7.1 | NA | Autism, ABC | NA | Inclusion: Autism score > 65 and IQ in the normal range (Cognitive functioning-KBIT and verbal IQ- BPVS) |
| Bölte et al. (2002) | 10 (10/0) | 27.2 (7.0) | NA | HFA, AS, ADI-R, ADOS-G | NA | Inclusion: IQ (Mean- 104.2, SD-17.1, range-58-126) |
| Bölte et al. (2006) | 10 (10/0) | 29.4 (5.9) | 25.8 (8.0) | Idiopathic autism, ICD-10 | NA | Inclusion: non verbal IQ (M = 104.2, SD = 17.1, range-58-126) |
| Bölte et al. (2015) | 32 (30/2) | 19.3 | NA | Autism, AS, Atypical autism/PDD-NOS, ICD-10, ADI-R, ADOS | | Inclusion: RSPM IQ ≥ 79, PBVT ≥ 8<br>Exclusion: Neurological disorders, mental disorders and genetic syndromes. |
| Cheng et al. (2018) | 24 (16/8) | 11.3 | 10.9 | ASD, DSM-5 | NA | Inclusion: WASI-IV > 70 |
| Faja et al. (2008) | 10 (10/0) | 19.6 (7.37) | 19.8 (3.42) | Autistic Disorder, AS, PDD-NOS, DSM-IV, ADI-R, ADOS | NA | Inclusion: WISC-III or WAIS-III IQ ≥ 85 |
| Faja et al. (2012) | 18 | 22.4 (4.4) | 21.5 (5.6) | HFA, ADI-R, DSM-IV | NA | Inclusion: Impaired face recognition according to the Wechsler Memory Scale (WAIS IQ) and Benton Test of Facial Recognition. |
| Fletcher-Watson et al. (2015) | 54 (43/11) | 49.3 (10.9) months | 49.96 (13.2) months | ASD, ADOS | Down syndrome (n = 2) | Inclusion: English speaking<br>Exclusion: Neurological disorders |
| Friedenson-Hayo et al. (2017)-1 | 15 (11/4) | 8.52 (1.11) | NA | ASD, ADOS-2, DSM-IV, ICD-10 | NA | Inclusion: Met the ADOS-2 cut-off criteria for ASD |
| Friedenson-Hayo et al. (2017)-2 | 74 (66/8) | Israel: 7.68 (1.2), Sweden: 6.95 (0.96) | Israel: 7.28 (1.3), Sweden: 7.24 (0.99) | ASD, ADOS-2, DSM-IV, ICD-10 | NA | Inclusion: Met the ADOS-2 cut-off criteria for ASD |
| Friedrich et al. (2015) | 13 (12/1) | 11.1 (2.3) | 11.8 (3.9) | ASD, ADOS, ADI-R | NA | Inclusion: WASI, WISC, M = 100, SD = 15 |
| Golan and Baron-Cohen (2006)-1 | 41 (31/10) | 30.5 (10.3), | 30.9 (11.2) | HFA, AS, DSM-IV, ICD-10, AQ | Depression, ADHD (n = 10) | Inclusion: WASI ≥ 70 |
| Golan and Baron-Cohen (2006)-2 | 26 (22/4) | 25.5 (9.3) | 24.4 (6.4) | HFA, AS, DSM-IV, ICD-10, AQ | NA | Inclusion: WASI ≥ 70 |
| Gordon et al. (2014) | 17 | 10.76 (3.59), | NA | ASD, ADOS, ADI | NA | Inclusion: KBIT-2 > 100 |
| Hopkins et al. (2011) | 49 (44/5) | LFA training: 10.31 (3.31), HFA training: 10.05 (2.30) | LFA control: 10.57 (3.2), HFA control: 9.85 (2.87) | LFA, HFA, DSM-IV, CARS | NA | Inclusion: KBIT-II > 70 for HFA group and KBIT-II < 70 in LFA group |
| Jeffries et al. (2016) | 3 (3/0) | Case 1: 3.67, Case 2: 3.58, Case 3: 5.92 | NA | Autism | NA | NA |
| Jouen et al. (2017) | 24 (24/0) | 6.85 (1.34) | 7.17 (1.62) | Autism, ASD, AS, ADI-R | NA | Inclusion: IQ ≥ 60, aged between 5-8 years, parents' motivation to complete study protocol. Participants matched for gender, age, IQ and study sites.<br>Exclusion: Organic syndrome and/or non-stabilised neuropediatric (e.g. seizures) or medical (e.g. diabetes) comorbidities |
| LaCava et al. (2007) | 8 (6/2) | 10.27 (1.24) | NA | AS, DSM-IV. ASDS, ASQ | NA | NA |
| Lacava et al. (2010) | 4 (4/0) | 8.6 (0.8) | NA | Autism, PDD-NOS | NA | NA |

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**Table 6** (*continued*)

| Author (Year) | N (male/ female) | Mean age* (SD) | | Diagnosis | Comorbidities | Inclusion and exclusion criteria |
|---|---|---|---|---|---|---|
| | | Intervention | Autism control group | | | |
| Lopata et al. (2016) | 36 (34/2) | 8.83 (1.47) | 8.83 (1.5) | Autism, AS, PDD-NOS, ADI-R | NA | Inclusion: WISC-IV > 70 (Verbal and Perceptual Reasoning of ≥ 80).<br>Exclusion: Behavioural difficulties |
| Malinverni et al. (2017) | 10 (10/0) | 5.3 (0.94) | NA | ASD, DSM-IV, ADOS, ADI-R | NA | Inclusion: WISC > 70<br>Exclusion: Participation in other psychological treatment and presence of changes in medication during the trial. |
| Miller et al. (2017) | 3 (3/0) | Case 1: 9<br>Case 2: 10<br>Case 3: 10 | NA | ASD | Limited verbal abilities and intellectual disability. | Inclusion: Able to understand the instruction 'look at me' and have an interest in computers. |
| Rice et al. (2015) | 31 (28/3) | 7.68 (1.45) | 7.87 (1.6) | ASD | NA | Inclusion: FSIQ > 70 |
| Russo-Ponsaran et al. (2014) | 3 | NA, Range: 8-14 years | NA | AS, PDD-NOS, ASD, SCQ, ADOS, ADI-R | NA | Inclusion: WASI IQ ≥ 80, participants with difficulties in recognising emotions- scoring at or below 80% on a MiX pretest. |
| Russo-Ponsaran et al. (2016) | 31 (26/5) | 10.6 (1.7) | 12.4 (1.9) | AS, PDD-NOS, ASD, SCQ, ADOS, ADI-R | NA | Inclusion: WASI IQ ≥ 80, SCQ ≥ 12, difficulties in emotion recognition |
| Serret et al. (2014) | 33 (31/2) | 11.4 (3.16) | NA | LFA, HFA, AS, PDD-NOS, DSM-IV-TR, ADI-R, ADOS | NA | Inclusion: WASI range 35-129, able to discriminate colours and use a computer |
| Silver and Oakes (2001) | 22 | 13.92 (0.92) | 14.75 (2.00) | Autism, AS | NA | Inclusion: Age equivalent of 7 years on BPVS. |
| Swettenham (1996) | 8 | 10.9 (3.8) | NA | Autism, DSM-III-R | NA | Inclusion: Matched verbal ability using the BPVS and non-verbal ability using the LIPS |
| Tanaka et al. (2010) | 79 (62/17) | 10.5 (3.8) | 11.4 (3.7) | Autistic disorder, AS, PDD-NOS, DSM-IV, ADI-R, ADOS-G | NA | Exclusion: Vision less than 20-100 in both eyes, difficulty in comprehending instructions<br>Inclusion: Face processing abilities above 2 or more SD below age expected range. |
| Thomeer et al. (2011) | 11 (8/3) | 9.09 (1.76) | NA | Autism, AS, PDD-NOS, ADI-R | NA | Inclusion: WISC-IV IQ ≥ 70, receptive or expressive language score ≥ 80 on CASL. |
| Thomeer et al. (2015) | 43 | 8.86 (1.39) | 8.57 (1.16) | Autism, AS, PDD-NOS, ADI-R | NA | Inclusion: WISC-IV IQ ≥ 70, receptive or expressive language score ≥ 80 on CASL.<br>Exclusion: psychiatric symptoms |
| White et al. (2018) | 20 (18/2) | 122.50 months | NA | ASD, ADOS-2 | NA | Inclusion: Age between 9 and 12 years, free from any co-occurring intellectual disability. WASI-II was administered. |

Note. ABC = Autism Behaviour Checklist; ADHD = Attention Deficit Hyperactivity Disorder; ADI-R = Autism Diagnostic Interview- Revised; ADOS = Autism Diagnostic Observation Schedule; ADOS-G = Autism Diagnostic Observation Schedule- Generic; AS = Asperger's syndrome; ASD = Autism Spectrum Disorders; ASQ = Autism Spectrum Quotient; ASDS = Asperger Syndrome Diagnostic Scale; BPVS = British Picture Vocabulary Scale; CARS = Childhood Autism Rating Scale; CASL = Comprehensive Assessment of Spoken Language; CAST = Childhood Asperger Syndrome Test; DSM = Diagnostic and Statistical Manual of Mental Disorders; FSIQ = Full Scale Intelligence Quotient; HFA = High functioning autism; ICD-10 = International Classification of Diseases 10$^{th}$ edition; IQ = Intelligence quotient; KBIT = Kaufman Brief Intelligence Test; LFA = Low functioning autism; LIPS = Leiter International Performance Scale; M = Mean; N = Total number; NA = Not available/ applicable; PDD-NOS = Pervasive Developmental Disorder- Not Otherwise Specified; PPVT = Peabody Picture Vocabulary Test; RSPM = Raven's Standard Progressive Matrices; SCQ = Social Communication Questionnaire; SD = Standard deviation; WAIS = Wechsler Adult Intelligence Scale; WASI = Wechsler Abbreviated Scale of Intelligence; WISC = Wechsler Intelligence Scale for Children.

et al., 2016; Thomeer et al., 2015).

*3.5.3. Transferability*

Measurements of transferability outcomes, or performance in areas not targeted by the CBI included social skills based on parental or teacher reports or naturalistic observations of social interactions (Beaumont & Sofronoff, 2008; Hopkins et al., 2011; Jouen et al., 2017; Lopata et al., 2016; Rice et al., 2015; Russo-Ponsaran et al., 2014; Thomeer et al., 2015), ASD symptomatology (Jouen et al., 2017; Lopata et al., 2016; Rice et al., 2015; Thomeer et al., 2015), brain activation using functional magnetic resonance imaging or electroencephalography (Bölte et al., 2006, 2015; Faja et al., 2012), language skills (Fletcher-Watson et al., 2015), emotion awareness (Russo-Ponsaran et al., 2014) and theory of mind (Rice et al., 2015; Silver & Oakes, 2001).

*3.5.4. Maintenance*

Four studies conducted a follow-up session ranging from four weeks to six months following the intervention to evaluate the maintenance of skills post intervention (Beaumont & Sofronoff, 2008; Fletcher-Watson et al., 2015; Russo-Ponsaran et al., 2016; Thomeer et al., 2015).

*3.5.5. Engagement*

Narrative synthesis of user engagement during CBI was reported in 12 experimental studies. Participants' level of engagement was captured via feedback from participants or parents and by examining attrition rates (Bernardini et al., 2014; Cheng et al., 2018; Fletcher-Watson et al., 2015; Fridenson-Hayo et al., 2017; Golan & Baron-Cohen, 2006; Jouen et al., 2017; LaCava et al., 2007; Lacava et al., 2010; Silver & Oakes, 2001; Thomeer et al., 2011, 2015).

*3.6. Quality assessment of studies*

Assessment of the methodological quality of the included studies, evaluated via the Standard Quality Assessment of Quantitative studies by Kmet et al. (2011) revealed few studies achieving a strong (12%, k = 4) (Beaumont & Sofronoff, 2008; Fletcher-Watson et al., 2015; Lopata et al., 2016; Thomeer et al., 2015) or good (24%, k = 8) methodological quality (Faja et al., 2012; Fridenson-Hayo et al., 2017; Golan et al., 2010; Hopkins et al., 2011; Jouen et al., 2017; Rice et al., 2015; Russo-Ponsaran et al., 2016). The majority achieved adequate methodological quality (38%, k = 13) (Bauminger-Zviely et al., 2013; Bölte et al., 2006, 2015; Faja et al., 2008; Friedrich et al., 2015; Gordon et al., 2014; LaCava et al., 2007; Serret et al., 2014; Silver & Oakes, 2001; Tanaka et al., 2010; Thomeer et al., 2011) and 26% (k = 9) of studies were judged to be of poor quality (Bernardini et al., 2014; Bernard-Opitz et al., 2001; Bölte et al., 2002; Lacava et al., 2010; Russo-Ponsaran et al., 2014; Swettenham, 1996).

Study quality was mainly limited due to high performance and detection bias, with blinding of participants and assessors rarely evaluated. Although 15 studies employed a randomised controlled trial design (Beaumont & Sofronoff, 2008; Bölte et al., 2002, 2006; Cheng et al., 2018; Faja et al., 2012; Fletcher-Watson et al., 2015; Fridenson-Hayo et al., 2017; Friedrich et al., 2015; Hopkins et al., 2011; Lopata et al., 2016; Rice et al., 2015; Russo-Ponsaran et al., 2016; Silver & Oakes, 2001; Tanaka et al., 2010; Thomeer et al., 2015), there was often limited reporting of randomisation protocols. Other factors contributing to low methodological quality included small sample sizes and heterogeneity between groups in baseline characteristics. Table 5 and Appendix E outline the methodological scoring for all studies.

*3.7. Serious game outcomes*

The 34 included studies described 24 social emotional CBI designed for use with autistic individuals. Five computer programs were evaluated in more than one study; the Frankfurt Test and Training of Facial Affect Recognition (Bölte et al., 2002, 2006; Bölte et al., 2015), MiX (Russo-Ponsaran et al., 2014, 2016), FaceSay (Hopkins et al., 2011; Rice et al., 2015), Mindreading (Golan & Baron-Cohen, 2006; LaCava et al., 2007; Lacava et al., 2010; Lopata et al., 2016; Thomeer et al., 2011, 2015) and a face processing program developed by Faja et al. (2012) and Faja et al. (2008). Bauminger-Zviely et al. (2013) evaluated two computer programs, No Problem and Join In, with findings presented separately given the differences in game features and targeted skills.

*3.7.1. Storyline*

Three computer programs integrated learning goals within a storyline running throughout the game (Beaumont & Sofronoff, 2008; Jeffries et al., 2016; Malinverni et al., 2017), with the remaining CBI having limited or no narrative components. The *'Secret Agent Society'* is set in the future with players informed they have been selected to undergo training as a secret agent completing graded training missions focusing on detecting the emotions and thoughts of potential suspects (Beaumont & Sofronoff, 2008). Towards the end of the program, players are promoted to an official 'Secret Agent'. The *'Look in My Eyes: Steam Train'* game assigns players the role of a train engineer, responsible for delivering a package to an assigned destination (Jeffries et al., 2016), achieved by completing a series of joint attention tasks and rewarded by collecting enough coal to power the delivery train. In *Pico's Adventure'* game, the player is required to initiate a friendship and cooperate with an alien character named Pico in a series of adventure tasks including repairing a spaceship and travelling to another planet (Malinverni et al., 2017).

While five games incorporated narrative aspects focused on players interacting reciprocally with game characters, their narratives were not integrated with learning objectives (Bernardini et al., 2014; Fridenson-Hayo et al., 2017; Friedrich et al., 2015; Serret et al., 2014; Swettenham, 1996). Within these games, characters typically adopt the role of a peer mentor engaging in dialogue with the goal of guiding players through the game. Several games incorporated artificial intelligence technology enabling game characters to adapt to player behaviour (Bernardini et al., 2014; Friedrich et al., 2015).

Five programs adopted a themed approach without narrative content (Bauminger-Zviely et al., 2013; Fletcher-Watson et al., 2015; Gordon et al., 2014; Hopkins et al., 2011; Tanaka et al., 2010). In some games, various themes within the game associated with individual sub-skills (Bauminger-Zviely et al., 2013; Hopkins et al., 2011; Tanaka et al., 2010). For example, *Let's Face It!* targets face recognition skills via a shooting theme called *'Zap It'* and joint attention goals in the another game called *'Eye Spy'* (Tanaka et al., 2010). Other games such as the *FaceMaze* and *FindMe* employed a consistent theme throughout the game (Fletcher-Watson et al., 2015; Gordon et al., 2014). In *FindMe*, players were required to find a person or the character's desired object hidden within different locations (Fletcher-Watson et al., 2015).

The 11 remaining computer programs focused on targeted goals via a question and answer format, and did not employ a narrative approach to target learning goals (Bauminger-Zviely et al., 2013; Bernard-Opitz et al., 2001; Bölte et al., 2002, 2006; Bölte et al., 2015; Cheng et al., 2018; Faja et al., 2008, 2012; Golan & Baron-Cohen, 2006; Jouen et al., 2017; LaCava et al., 2007; Lacava et al., 2010; Lopata et al., 2016; Miller et al., 2018; Russo-Ponsaran et al., 2016, 2014; Silver & Oakes, 2001; Thomeer et al., 2011, 2015; White et al., 2018).

*3.7.2. Goal-Directed learning*

Only four programs incorporated long term objectives (Beaumont & Sofronoff, 2008; Jeffries et al., 2016; Malinverni et al., 2017; Serret et al., 2014). *'Secret Agent Society'* and *'Look in My Eyes: Steam Train'* required players to graduate as a 'Secret Agent' or deliver a package, respectively (Beaumont & Sofronoff, 2008; Jeffries et al., 2016). The final aim of *'Pico's Adventures'* was to assist the alien character safely back to its planet (Malinverni et al., 2017). Although *JeStiMule* did not include a narrative component, the long term objective of the game was to collect puzzle pieces with the goal of completing the 30-piece puzzle by the end of the game (Serret et al., 2014).

Eight CBI were classified as having medium term goals, requiring players to reach a threshold of performance before progressing to the next stage of the game (Bauminger-Zviely et al., 2013; Bernardini et al., 2014; Fletcher-Watson et al., 2015; Friedrich et al., 2015; Hopkins et al., 2011; Jouen et al., 2017; Rice et al., 2015; Tanaka et al., 2010). Some games employed a point system to implement medium term goals, with players' performance rewarded with a set number of points allowing them to receive an award or progress within the game (Fletcher-Watson et al., 2015; Friedrich et al., 2015; Hopkins et al., 2011; Rice et al., 2015; Tanaka et al., 2010). One game required achievement of prerequisite learning objectives before allowing players to progress to the next objective (Bauminger-Zviely et al., 2013). In *ECHOES,* the multi-sensory garden was divided into zones representing various learning activities, with some requiring the players to complete a series of tasks before achieving the end-goal of the activity (Bernardini et al., 2014).

Twelve CBI incorporated short term learning objectives largely delivered via repeated presentation of differing social stimuli (Bernard-Opitz et al., 2001; Bölte et al., 2002, 2006; Bölte et al., 2015; Cheng et al., 2018; Faja et al., 2008, 2012; Fridenson-Hayo et al., 2017; Golan & Baron-Cohen, 2006; Gordon et al., 2014; LaCava et al., 2007; Lacava et al., 2010; Lopata et al., 2016; Miller et al., 2018; Russo-Ponsaran et al., 2016, 2014; Silver & Oakes, 2001; Swettenham, 1996; Thomeer et al., 2011, 2015; White et al., 2018).

*3.7.3. Rewards and feedback*

All CBI included some reward system, with the exception of *Join In!,* which only provided feedback (Bauminger-Zviely et al., 2013). Four programs incorporated both reward and feedback systems within the game (Gordon et al., 2014; Silver & Oakes, 2001; Swettenham, 1996). Rewards system typically took the form of auditory, visual or textual positive reinforcement, with some games rewarding players with collectables such as points or objects (Beaumont & Sofronoff, 2008; Bernard-Opitz et al., 2001; Cheng et al., 2018; Fletcher-Watson et al., 2015; Fridenson-Hayo et al., 2017; Golan & Baron-Cohen, 2006; Gordon et al., 2014; Hopkins et al., 2011; Jeffries et al., 2016; Jouen et al., 2017; LaCava et al., 2007; Lacava et al., 2010; Lopata et al., 2016; Malinverni et al., 2017; Miller et al., 2018; Rice et al., 2015; Serret et al., 2014; Tanaka et al., 2010; Thomeer et al., 2011, 2015; White et al., 2018). Few CBI incorporated feedback systems which provided players with information on their progress throughout the intervention. Typically, feedback systems relied on visual progress bars (Gordon et al., 2014; Serret et al., 2014) or provided players with hints or prompts (Bauminger-Zviely et al., 2013; Silver & Oakes, 2001; Swettenham, 1996).

*3.7.4. Increasing levels of difficulty*

Four CBI employed a variety of contexts, increasing the level of the difficulty within the game by introducing increasingly complex stimuli with additional emotional or environmental clues, presenting more trials and distractors (Beaumont & Sofronoff, 2008; Faja et al., 2008, 2012; Fletcher-Watson et al., 2015; Serret et al., 2014). Several programs demonstrated some attempt to adjust the level of difficulty of the game by increasing the speed of presentation, number of completed trials or distractors (Bauminger-Zviely et al., 2013; Friedrich et al., 2015; Jeffries et al., 2016; Jouen et al., 2017; Russo-Ponsaran et al., 2014, 2016). Other programs addressed complexity through addressing skills in different stages and contexts (Bauminger-Zviely et al., 2013; Bernard-Opitz et al., 2001; Bölte et al., 2002, 2006; Bölte et al., 2015; Cheng et al., 2018; Fridenson-Hayo et al., 2017; Malinverni et al., 2017; Silver & Oakes, 2001; White et al., 2018) or adjusting the complexity of emotions, without arranging the tasks in a stepwise level of difficulty (Golan & Baron-Cohen, 2006; Hopkins et al., 2011; Rice et al., 2015). Overall, four CBI maintained a consistent level of difficulty throughout the game (Bernardini et al., 2014; Gordon et al., 2014; Swettenham, 1996).

*3.7.5. Individualisation*

Individualisation features were either implemented using an in-built computer system or manually customised by a facilitator or the player. Among the included CBI, individualisation features were not reported in 14 programs (Beaumont & Sofronoff, 2008; Bernardini et al., 2014; Bernard-Opitz et al., 2001; Cheng et al., 2018; Faja et al., 2008, 2012; Fletcher-Watson et al., 2015; Fridenson-Hayo et al., 2017; Friedrich et al., 2015; Gordon et al., 2014; Malinverni et al., 2017; Miller et al., 2018; Silver & Oakes, 2001; Swettenham, 1996; White et al., 2018). Only three programs reported in-built individualisation features, using starting points individualised to the player or automatic functions adapted according to the players' progress (Bölte et al., 2002, 2006; Bölte et al., 2015; Friedrich et al., 2015; Serret et al., 2014). For example, in a neurofeedback game, players were required to achieve a threshold of 80% before progressing to the next level (Friedrich et al., 2015) or in ***JeStiMule,*** a failed task was automatically presented in subsequent trials (Serret et al., 2014).

Some interventions individualised the program according to facilitator's judgement (Bauminger-Zviely et al., 2013; Jouen et al., 2017; Russo-Ponsaran et al., 2014, 2016) or by allowing players to autonomously customise their own game pathways (Golan et al., 2010; Golan & Baron-Cohen, 2006; Hopkins et al., 2011; Jeffries et al., 2016; LaCava et al., 2007; Lacava et al., 2010; Lopata et al., 2016; Rice et al., 2015; Tanaka et al., 2010; Thomeer et al., 2011, 2015). These external individualisation strategies were typically used to adjust the level of difficulty of the game tasks.

*3.7.6. Summary of design quality*

Overall, the minority of social emotional CBI aimed at autistic individuals integrated Serious Game principles, with interventions included in this review obtaining on average a Serious Game score of 45% (limited). Table 7 provides an overview of the classification of the included studies in relation to the Serious Game principles (Whyte et al., 2015).

*3.8. Effects of interventions: Social emotional outcomes*

*3.8.1. Close generalisation outcomes*

Fifteen of the 17 included studies evaluated close generalisation outcomes. The overall random effects meta-regressions for close generalisation outcomes was significant ($g = 0.68$. 95% CI [0.50-0.86], $p < 0.01$), indicating that CBI had a medium effect in remediating social emotional close generalisation outcomes for autistic individuals (Fig. 2). The overall heterogeneity for close generalisation social emotional outcomes was not significant ($Q = 17.55$, $p = 0.23$, $I^2 = 27.33\%$). Moderation analysis, examining the influence of Serious Game features on the effect of CBI on close generalisation outcomes was not significant ($g = 0.06$, $p = 0.61$). Intervention duration and age did not reveal any significant moderating effects. The Egger's regression test was significant ($p < 0.02$), suggesting that publication bias may have impacted these results. The trim and fill method accounted for three missing studies due to publication bias, resulting in an adjusted effect size of $g = 0.61$ (Appendix F) (Fig. 3).

*3.8.2. Distant generalisation outcomes*

Eight studies evaluated distant generalisation outcomes relating to social communication, emotion regulation, emotion imitation, emotion recognition and emotion awareness. Social emotional CBI revealed a medium effect size for distant generalisation outcomes ($g = 0.46$, 95% CI [0.14–0.78], $p = 0.01$). The heterogeneity of effect sizes in distant generalisation outcomes between social emotional CBI was moderate ($Q = 17.38$, $p = 0.02$, $I^2 = 60.53\%$). Importantly, a significant moderating effect of Serious Game features was evident, suggesting that increased Serious Game feature implementation was associated with greater CBI-linked improvements in distant generalisation outcomes ($g = 0.31$, $p = 0.03$). Intervention duration and age did not reveal any significant moderating effects.

*3.8.3. Transferability outcomes*

Eleven studies measured six transferability outcomes, behaviour, social skills, ASD symptomatology, brain activation, language and theory of mind scores. The potential for social emotional CBI to improve skills outside of the training context was marginally significant and associated with a small effect size of 0.32 (95% CI [-0.01- 0.65], $p = 0.06$). Effect sizes for transferability outcomes across studies were moderately heterogeneous ($Q = 25.72$, $p < 0.01$, $I^2 = 63.76\%$). Serious Game features demonstrated a significant moderating effect on CBI-linked improvements in transferability outcomes ($g = 0.34$, $p = 0.03$), indicating that higher integration of Serious Game principles was associated with improved transferability outcomes. Intervention duration and age did not reveal any significant moderating effects. Non-significant results were observed for the Egger's test ($p = 0.21$) and visual inspection of funnel plots showed a symmetrical distribution of effect sizes, suggesting a low likelihood that publication bias impacted these results (Appendix F) (Fig. 4).

*3.8.4. Maintenance outcomes*

Meta-analysis of maintenance outcomes for social emotional CBIs revealed an overall small effect ($g = 0.31$, 95% CI [0.03-0.59], $p = 0.03$) across all outcomes post-intervention. Maintenance outcomes were significantly heterogeneous ($Q = 29.24$, $p < 0.01$, $I^2 = 67.39\%$). Incorporating Serious Game principles in CBIs demonstrated no significant impact in improving social emotional outcomes post intervention ($g = -0.12$, $p = 0.26$). Intervention duration and age did not reveal any significant moderating effects. Egger's test revealed no significant effects in funnel plot asymmetry ($p = 0.88$), suggesting a low likelihood that publication bias impacted on the overall effect size (Appendix F).

Sub-group analyses of close ($g = 0.53$, 95% CI [-0.12-1.18], $p = 0.11$) and distant generalisation ($g = 0.46$, 95% CI [-0.02-0.93],

**Table 7**
Serious game principles- Classifications of studies.

| Author (Year) | Targeted Domain | Serious Game principles | | | | | Serious Game Score |
|---|---|---|---|---|---|---|---|
| | | Storyline | Goals | Reward | Difficulty Increases | Individualised | |
| Bauminger-Zviely et al. (2013) | Social collaboration | Themed | Medium | None | Some | Facilitator | 4 |
| Bauminger-Zviely et al. (2013) | Social conversation | None | Medium | Reward | Some | Choice/ Facilitator | 4 |
| Beaumont and Sofronoff (2008) | Social interaction (emotion management, initiating and maintaining interactions, managing bullies) | Yes | Long | Reward | Yes | None | 7 |
| Bernardini et al. (2013) | Joint attention and symbol use | Some | Medium | Reward | None | None | 3 |
| Bernard-Opitz et al. (2001) | Social problem solving | None | Short | Reward | Some | None | 3 |
| Bölte et al. (2002), 2006; Bölte et al. (2015) | Emotion recognition | None | Short | Reward | Some | Yes | 5 |
| Cheng et al. (2018) | Emotion recognition | None | Short | Reward | Some | None | 3 |
| Faja et al. (2007); Faja et al. (2012) | Face processing | None | Short | Reward | Yes | None | 4 |
| Friedenson-Hayo et al. (2017) | Emotion recognition | Some | Short | Reward | Some | None | 4 |
| Fletcher-Watson et al. (2015) | Joint attention | Themed | Medium | Reward | Yes | None | 5 |
| Friedrich et al. (2015) | Social imitation | Some | Medium | Reward | Some | Yes | 6 |
| Golan and Baron-Cohen (2006); LaCava et al. (2007), 2010; Lopata et al. (2016); Thomeer et al. (2011), 2015 | Emotion recognition | None | Short | Reward | Some | Choice | 4 |
| Gordan et al. (2014) | Emotion imitation | Themed | Short | Both | None | None | 4 |
| Hopkins et al. (2011); Rice et al. (2015) | Face processing | Themed | Medium | Reward | Some | Choice | 5 |
| Jeffries et al. (2016) | Joint attention | Yes | Long | Reward | Some | Choice | 7 |
| Jouen et al. (2017) | Joint attention | None | Medium | Reward | Some | Facilitator | 4 |
| Malinverni et al. (2017) | Social initiation | Yes | Long | Reward | Some | None | 6 |
| Miller et al. (2017) | Joint attention | None | Short | Reward | None | None | 2 |
| Russo-Ponsaran et al. (2014), 2016 | Emotion recognition | None | Short | Reward | Some | Facilitator | 4 |
| Serret et al. (2014) | Emotion recognition | Some | Long | Both | Yes | Yes | 9 |
| Silver and Oakes (2001) | Emotion recognition and theory of mind | None | Short | Both | Some | None | 4 |
| Swettenham (1996) | Theory of mind | Some | Short | Both | None | None | 4 |
| Tanaka et al. (2010) | Face processing | Themed | Medium | Reward | Some | Choice | 5 |
| White et al. (2018) | Emotion recognition and expression | None | Short | Reward | Some | None | 2 |

$p$ = 0.06) maintenance outcomes indicated a non-significant effect for autistic individuals participating in a social emotional CBI maintaining these skills post-intervention. There was a negligible effect for CBI in maintaining transferable outcomes post intervention ($g$ = 0.03, 95% CI [-0.30-0.37], $p$ = 0.84) (Fig. 5).

*3.8.5. Engagement outcomes*

While few experimental studies reported attrition rates (Bernardini et al., 2014; Fletcher-Watson et al., 2015; Fridenson-Hayo et al., 2017; Golan & Baron-Cohen, 2006; Jouen et al., 2017), available rates revealed that on average 19.17% of participants dropout from CBI. Reported attrition rates varied across studies, ranging from low (0–11%) (Fletcher-Watson et al., 2015; Jouen et al., 2017) to high (34%) (Bernardini et al., 2014). Qualitative reports from parents and participants revealed generally high levels of satisfaction with CBI (Cheng et al., 2018; Fletcher-Watson et al., 2015; LaCava et al., 2007; Lacava et al., 2010; Thomeer et al., 2011, 2015). Two feasibility studies of the *Mindreading* game reported participants preferentially spent the majority of their time in the 'games' and 'reward' zones, finding the repetitive nature of the game uninteresting (LaCava et al., 2007; Lacava et al., 2010). Engagement outcomes are summarised in Table 8.

## 4. Discussion

Using a Serious Game Assessment Tool to quantify the implementation of Serious Game principles in CBI for autistic individuals, the current review investigated the influence of Serious Game design on the effect of CBI in remediating the social emotional skills of autistic individuals. While CBI was associated with an overall improvement in social emotional outcomes, interestingly, this effect was further moderated by the inclusion of Serious Game design principles. Specifically, a greater implementation of Serious Game design principles in designing CBI was associated with greater improvements in distant generalisation and transferability outcomes. These findings support the hypothesis that integrating Serious Game principles in social emotional CBI will result in improved outcomes for autistic participants (Whyte et al., 2015).

The present review examined for the first time the effect of CBI for autistic individuals across a spectrum of scaffolded social

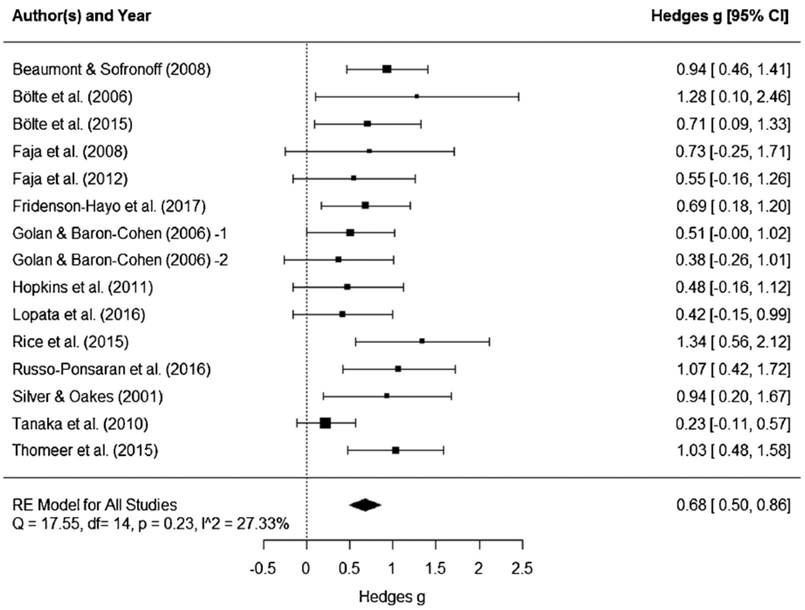


**Fig. 2.** Forrest plot comparison for pre-post-test close generalisation outcomes between social emotional computer based interventions and control groups.

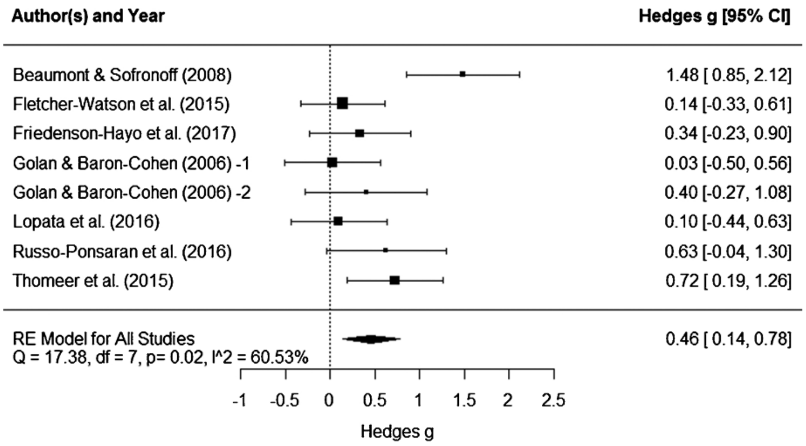


**Fig. 3.** Forrest plot comparison for pre-post-test distant generalisation outcomes between social emotional computer based interventions and control groups.

emotional outcomes. Meta-analyses revealed an overall positive effect of CBI in targeting close generalisation, distant generalisation, transferability to other skills and maintenance of intervention gains for autistic individuals, with the largest effect size observed for close generalisation outcomes ($g = 0.68$). Medium effect size was found for distant generalisation outcomes ($g = 0.46$), which is comparable to a previous meta-analysis evaluating the overall effect of innovative technologies for autistic individuals ($d = 0.47$)

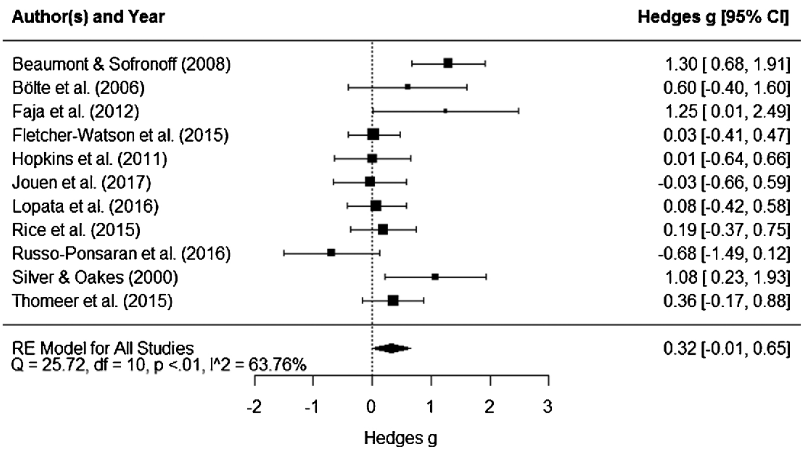


**Fig. 4.** Forrest plot comparison for pre-post-test transferability outcomes between social emotional computer based interventions and control groups.

(Grynszpan et al., 2014). A medium effect was similarly observed for social skills groups for autistic individuals (Gates et al., 2017; Reichow et al., 2012). Given the comparable results, it is unclear whether social emotional skills are better targeted in group based settings or through CBI. CBI may be a promising avenue for future research to explore, given their key features leverage the recognised strengths of autistic individuals as visual learners and are aligned with their interest in computers (Heimann et al., 1995; Shane & Albert, 2008).

It is interesting to note the influence of Serious Game design principles on distant generalisation and transferability to skills, extending those skills specifically targeted within the interventions. It has been argued that impacting the distant generalisation of skills is a criteria of critical importance when evaluating the effect of a given intervention (Bölte, Golan, Goodwin, & Zwaigenbaum, 2010). The ultimate effect of interventions in targeting aspects of impairment such as emotion recognition must be judged in relation to their transfer to everyday functioning (Bölte et al., 2017). Specifically, we posit that improvements in distant generalisation are likely to be more indicative of genuine improvement in a given social emotional skill than improvements in close generalisation, given these skills are assessed in different contexts. Measures of distant generalisation likely reflect the generalisation of targeted skills to everyday contexts supporting improvements in social abilities not explicitly addressed in the intervention itself. Paralleling this argument, we suggest that the observed increase in transferability to other skills associated with the implementation of Serious Game features in CBI provides some evidence that these features facilitate improvement across a broader range of social emotional outcomes. Collectively, the finding that Serious Game features may specifically enhance distant generalisation and transferability outcomes further bolsters its relevance for the development of social emotional CBI.

### *4.1. Limitations*

In addition to examining the influence of Serious Game design on CBI social emotional outcomes, we sought to understand if these game designs increased participant engagement. While previous reports propose that CBI may be a motivating platform for autistic individuals to learn complex skills (Heimann et al., 1995), understanding of the motivational value of such interventions is limited by reporting of engagement outcomes across the included studies. Only five available studies (Bernardini et al., 2014; Fletcher-Watson et al., 2015; Fridenson-Hayo et al., 2017; Golan & Baron-Cohen, 2006; Jouen et al., 2017) reported attrition rates, despite it being specified as one of the reporting requirements under the Consolidated Standards of Reporting Trials (CONSORT) guidelines. Future research evaluating CBI may benefit from the reporting of attrition rates or other potential outcome measurements for engagement, such as gameplay statistics or participants' satisfaction during the game (Fletcher-Watson, 2014).

A number of other inherent limitations of the present review must also be acknowledged. It was evident that a number of studies evaluating CBI did not implement a formal randomised controlled trial design. While we included these studies in the meta-analysis in order to best represent the existing literature, the inclusion of non-randomised controlled trials in the analysis may have introduced performance and detection bias due to a lack of blinding of participants and assessors. Similarly, few studies provided a description of allocation concealment and sequence generalisation, suggesting the need for greater transparency of reporting.

Small sample size and insufficient reporting of participants' characteristics may further limit the generalisability of the results. Participants included in current social emotional CBI in ASD research were largely younger males with high cognitive functioning abilities. The inclusion of larger more representative samples and improving the reporting of participants' characteristics will assist

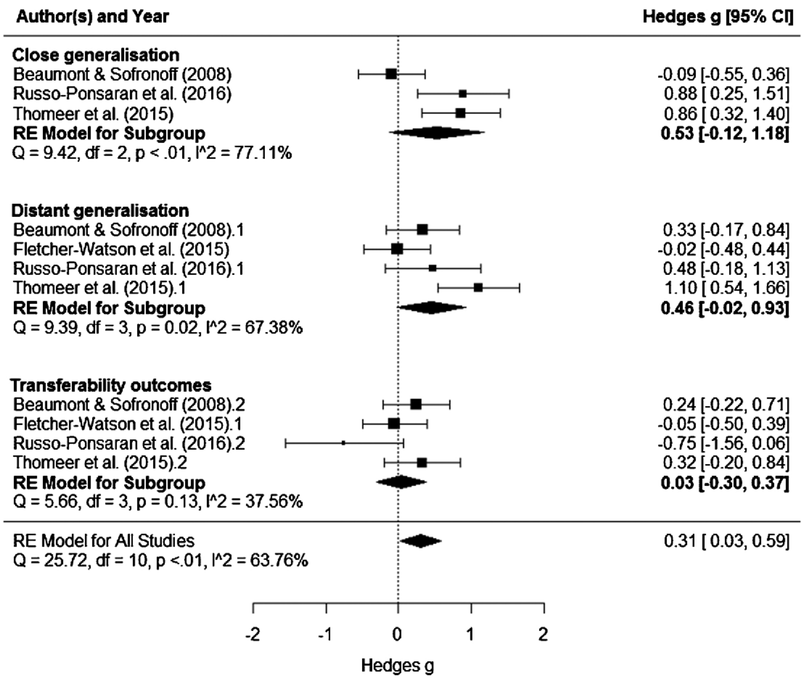


**Fig. 5.** Forrest plot comparison for pre-post-test maintenance outcomes between social emotional computer based interventions and control groups.

**Table 8**
User engagement of participants with ASD in social emotional computer based interventions.

| Author (Year) | Engagement outcomes | |
|---|---|---|
| | Attrition rate % | Qualitative reports |
| Bernardini et al. (2014) | 34 | – |
| Cheng et al. (2018) | – | Most participants reported that they enjoyed the game and found it beneficial in learning facial expressions. |
| Fletcher-Watson et al. (2015) | 11 | High percentage of enjoyment reported by parents (92%) and children (96%) |
| Fridenson-Hayo et al. (2017) | 21 | – |
| Golan and Baron-Cohen (2006)-1 | 21 | – |
| Golan and Baron-Cohen (2006)-2 | 28 | – |
| Jouen et al. (2017) | 0 (Three children had lower participation rates. Total participation rates = 39.9%) | – |
| LaCava et al. (2007) | – | Participants preferred the "game zone" but found the repetition uninteresting. |
| Lacava et al. (2010) | – | Participants enjoyed "games" and "reward" zones in the game. |
| Silver and Oakes (2001) | – | – |
| Thomeer et al. (2011) | – | High satisfaction rates reported. |
| Thomeer et al. (2015) | – | Parents and children reported high satisfaction rates |

future researchers and clinicians to make informed decisions on the suitability of the CBI for their clients (Berggren et al., 2017).

Heterogeneity in social emotional outcome measures was also observed, making it challenging to draw definite conclusions on the efficacy of CBI on distant generalisation outcomes. Limited availability of standardised assessments evaluating distant generalisation outcomes may in part contribute to the heterogeneity in the findings. Most researchers relied on self-developed measures to capture the potential efficacy of Serious Game design in improving distant generalisation outcomes, mainly utilising parent or self-reports measures of social emotional improvements in everyday activities. Previous social skills group meta-analyses reported effect sizes differences in parent, self-reported and observer and self-reported outcome measures (Gates et al., 2017; Wolstencroft et al., 2018). Future research should consider developing and testing the reliability and validity of standardised assessments evaluating social emotional skills outside of the training context.

The absence of a moderating effect for intervention duration observed in the present review may be attributed to the heterogeneous nature of the CBI evaluated across studies. Potential confounding factors such as the presence of a facilitator (Golan & Baron-Cohen, 2006; Jouen et al., 2017) or integrating CBI with social skills groups (Beaumont & Sofronoff, 2008; Lopata et al., 2016; Rice et al., 2015) may have lengthen the duration of the intervention beyond that actually reported. Additionally, underrepresentation of older autistic individuals (21%) in this review could in part have contributed to the observed absence of significant moderating effect of age. Previous meta-analysis on technological based interventions in ASD reported comparable non-significant moderating effects for intervention duration, age and IQ on intervention outcomes (Grynszpan et al., 2014). The authors concluded that this was likely due to heterogeneous methodologies, small sample sizes, and the lack of representation from older and lower functioning participants.

### *4.2. Future implications*

The findings of this review provide insights into the potential for Serious Game design principles to enhance social emotional outcomes of autistic individuals. Given the present finding that Serious Games may specifically enhance the distant generalisation and transferability outcomes of social emotional CBI, future research may seek to identify the underlying mechanisms of this effect. We speculate that the opportunity for individuals to experiment with skills in a multi-modal environment may plausibly underpin the increased efficacy of Serious Game designs in improving distant generalisation skills and transfer to other skills. For example, CBI incorporating narrative elements and increasing levels of difficulty such as the Secret Agent Society (Beaumont & Sofronoff, 2008) and JeStimule (Serret et al., 2014) offer the unique opportunity for individuals to contextualise their learning across multiple contexts and graded levels of difficulty, rather than being limited by a singular static environment. This approach likely results in more robust skill development and, a greater generalisation of learnt skills.

Future research could identify the most appropriate types of game designs for autistic individuals. While the present findings take an important step forward in demonstrating the relevance of Serious Game design in CBI, such interventions will only be as effective as they are accepted by their intended populations. Approaches to developing CBI should include co-production techniques involving autistic individuals in determining the appropriateness and motivational appeal of the CBI features (Frauenberger, Good, & Keay-Bright, 2011). Further research engaging autistic individuals is required to identify specific narrative styles promoting their learning and motivation (Tang, Falkmer, Bölte, & Girdler, 2018).

## 5. Conclusion

The results from this review suggest that currently available social emotional CBI present some limitations in the application of Serious Game design principles. The meta-analyses revealed that implementing social emotional CBI resulted in a small to large overall improvements in social emotional skills in autistic individuals, with the largest effect for close generalisation skills. Social emotional improvements were found to be moderated by the increased application of Serious Game principles. This result highlights the relevance of Serious Game principles in enhancing the outcomes of social emotional CBI, with specific reference to improving distant generalisation and transferability skills. The Serious Game Assessment Tool developed as part of this review enables future research to systematically evaluate the implementation of Serious Game principles in the design of game-based interventions. Future research may consider using the five Serious Game design principles as a potential avenue for guiding the development of prospective interventions.

## Acknowledgements

The authors would like to acknowledge Matthew Albrecht for providing software support, Richard Parsons and Torbjorn Falkmer for their statistical advice. Funding for this study was provided by the Cooperative Research Centre for Living with Autism (Autism CRC) [Project Number 3.032RS]. JT was supported by funding from an Australian Postgraduate Award scholarship from the Australian Federal Government. The funding bodies had no role in the study design, collection, analysis or interpretation of the data, writing the manuscript. Approval was obtained from Autism CRC for submission of manuscript for publication.

## Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at https://doi.org/10.1016/j.rasd.2019.101412.

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# Chapter 3 : Stakeholders' perspectives on design considerations for social emotional interventions for autistic adults

This chapter presents a manuscript that has been published in Journal of Autism and Developmental Disorders, **impact factor 2.786**:

**Tang, J. S. Y**., Falkmer, M., Chen, N. T. M., Bölte, S., & Girdler, S. (2018). Designing a serious game for youth with ASD: Perspectives from end-users and professionals. *Journal of Autism and Developmental Disorders*, *49*(3), 978–995. https://doi.org/10.1007/s10803-018-3801-9

# Author contribution statement: Chapter 3

As co-authors of the paper entitled, 'Designing a serious game for youth with ASD: Perspectives from end-users and professionals', we confirm that Julia Tang has been the principal research and has made the following contributions:

- Conceptualisation and design of the research;
- Data collection, analysis and interpretation (Focus groups were facilitated by the PhD candidate; and a second moderator, another PhD Candidate was present to take field notes)
- Writing the manuscript and critical appraisal of the findings; and
- Corresponding author for communication with the journal.

Our contribution to the paper was consistent with the role of supervisors and involved the following contributions:

- Assistance with conceptualisation and design of the research;
- Assistance with data collection, analysis and interpretation; and
- Review and editing of the manuscript

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|---|---|---|
| Signed: | Marita Falkmer | Date: 28.05.2020 |
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# Preface

Findings from Chapter 2 highlighted varying intervention applications for supporting the social emotional skills of autistic adults, providing the rationale to explore suitable intervention features for supporting the social emotional understanding of autistic adults. Chapter 3 is the first study in *Phase 2: Development* of this thesis, aiming to identify the fundamental social emotional learning content from the perspectives of autistic individuals, and professionals in autism. Given that Chapter 2 provided empirical evidence of serious game application in improving the distant generalisation and transferability outcomes of autistic individuals, the views of autistic individuals and professionals were mapped against the serious game design principles. While the focus of Chapter 3 findings were framed under serious game principles, the results provided helpful recommendations that are easily applicable for other interventions modalities targeting the social emotional skills of autistic adults.

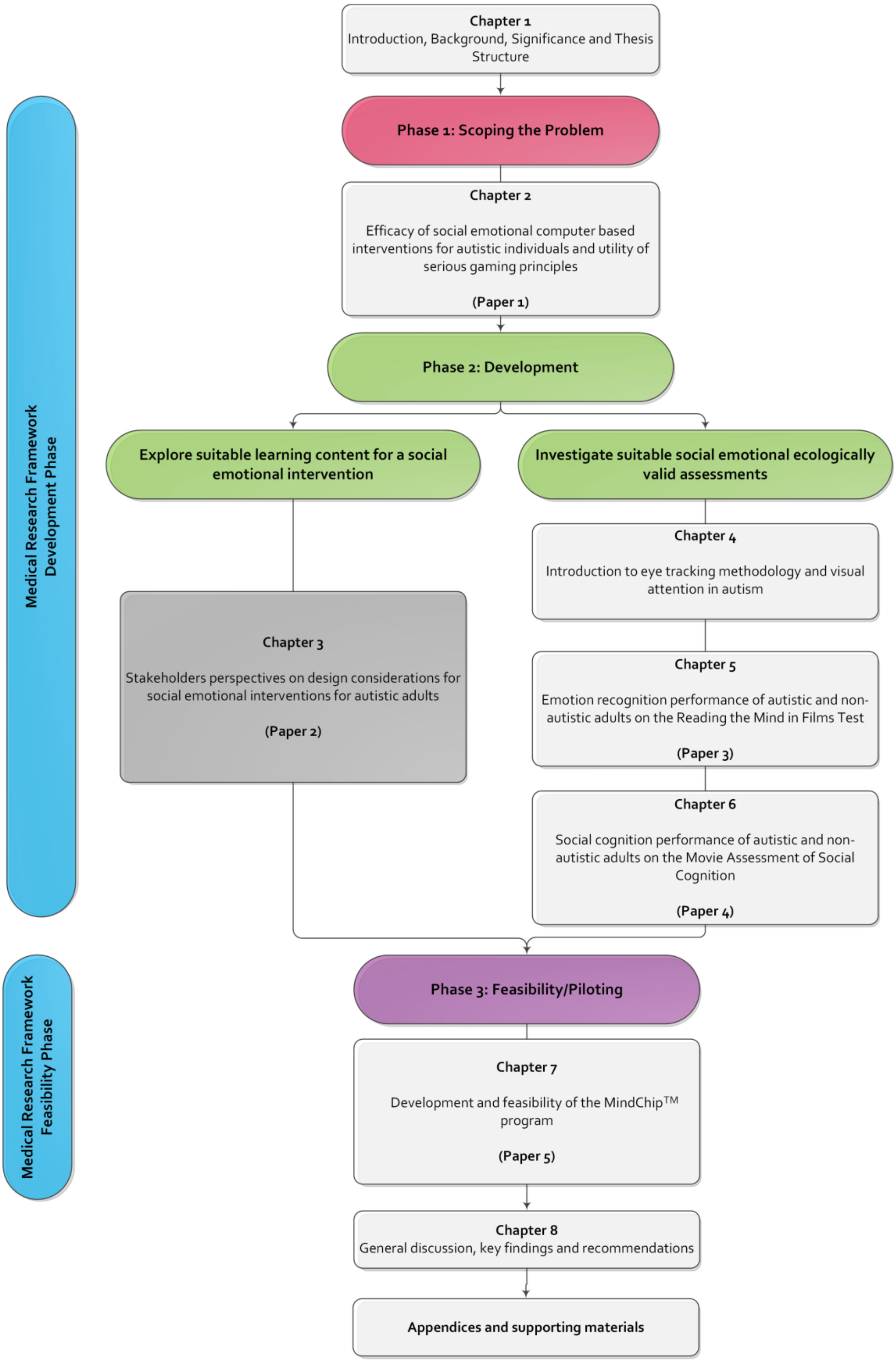


**Figure 3.1. Thesis structure Chapter 3.**

Journal of Autism and Developmental Disorders
https://doi.org/10.1007/s10803-018-3801-9

ORIGINAL PAPER

# Designing a Serious Game for Youth with ASD: Perspectives from End-Users and Professionals

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**Abstract**
Recent years have seen an emergence of social emotional computer games for individuals with Autism Spectrum Disorder (ASD). These games are heterogeneous in design with few underpinned by theoretically informed approaches to computer-based interventions. Guided by the serious game framework outlined by Whyte et al. (Journal of Autism and Developmental Disorders 45(12):1–12, 2014), this study aimed to identify the key motivating and learning features for serious games targeting emotion recognition skills from the perspectives of 11 youth with ASD and 11 experienced professionals. Results demonstrated that youth emphasised the motivating aspects of game design, while the professionals stressed embedding elements facilitating the generalisation of acquired skills. Both complementary and differing views provide suggestions for the application of serious game principles in a potential serious game.

**Keywords** Adolescent · Autism spectrum disorder · Computer · Educational game · Technology

Alterations in emotion recognition are a hallmark characteristic of Autism Spectrum Disorder (ASD) (American Psychiatric Association 2013; Bal et al. 2010; Baron-Cohen et al. 1997), contributing to the challenges these individuals experience in social environments (Howlin et al. 2013; Levy and Perry 2011). Findings from eye tracking and neuroimaging studies suggest that individuals with ASD differ in their emotion processing compared to their typically developing peers (Black et al. 2017; Harms et al. 2010), a pattern most apparent in studies presenting more challenging stimuli including complex emotions or increased performance demands such as shorter presentation times (Harms et al. 2010). This divergent pattern in emotion recognition performance in ASD persists into adulthood (Black et al. 2017; Rump et al. 2009), highlighting the importance of developing emotion recognition interventions appropriate for adults.

Research has explored several social emotional intervention modalities for individuals with ASD (Ramdoss et al. 2012; Rao et al. 2008), in particular platforms harnessing their preference for 'systemising' or rule-based environments (Baron-Cohen et al. 2003). Computer-based interventions (CBI) given their inherent predictability and systemisation, provide a modality capitalising on these preferences (Charlop-Christy et al. 2000; Golan and Baron-Cohen 2006). Preliminary evidence highlights the high levels of acceptability and efficacy of CBI for individuals with ASD (Grynszpan et al. 2014; Mazurek et al. 2015). Social skills training delivered via CBI is reportedly engaging for individuals with ASD (Williams et al. 2002), facilitating their

**Electronic supplementary material** The online version of this article (https://doi.org/10.1007/s10803-018-3801-9) contains supplementary material, which is available to authorized users.

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Published online: 30 October 2018

autonomous exploration of complex skills within a safe and secure environment.

While previous research demonstrates the efficacy of CBI in improving emotion recognition skills under testing conditions (Bölte et al. 2002, 2006; Golan and Baron-Cohen 2006; Serret et al. 2014; Silver and Oakes 2001; Williams et al. 2002), the generalisation of skills to everyday contexts appears limited or is as yet unknown (Ramdoss et al. 2012; Wainer and Ingersoll 2011). Currently, available serious games for individuals with ASD employ a variety of design approaches in targeting emotion recognition skills (Grossard et al. 2017). While some games are relatively simplistic, embedding photographs and videos of emotions via a question and answer format (Bölte et al. 2006; Golan and Baron-Cohen 2006; Russo-Ponsaran et al. 2016) or decorative gaming elements within traditional learning approaches (Fridenson-Hayo et al. 2017; Hopkins et al. 2011), others employ more sophisticated gamification techniques including elaborate virtual environments (Serret et al. 2014) or complex narratives (Beaumont and Sofronoff 2008).

Increasingly, developers of CBI are adopting the principles of 'serious game design', aiming to strengthen the effect of these interventions and the generalisation of skills to everyday contexts (Whyte et al. 2014). Serious games integrate both pedagogical theories and motivational principles of game design with the goal of facilitating skill acquisition (de Freitas 2006). Fundamentally, serious games acknowledge the value of motivational design elements in promoting users' learning experiences (Boyle et al. 2011; Catalano et al. 2014; Habgood and Ainsworth 2011). Serious games show some promise in improving the emotion recognition skills of individuals with ASD, however there is a need to understand the utility of serious game design in improving these interventions (Boucenna et al. 2014; Grossard et al. 2017).

Inconsistencies in the efficacy of CBI in improving the social emotional skills of individuals with ASD could be underpinned by variability in game developers' consideration of the learning styles and needs of individuals with ASD (Grossard et al. 2017). The operationalisation of design frameworks facilitates a design process more likely to align with the learning needs of individuals with ASD and the core objectives of an intervention (Rooney 2012). While multiple approaches to serious game design have been suggested (Grossard et al. 2017; Whyte et al. 2014; Yusoff 2010), Whyte et al. (2014) propose a framework aimed at enhancing the engagement of users with ASD, while also supporting the generalisation of learnt skills to naturalistic environments. This framework consists of five principles: (1) contextualising learning experiences via a motivating storyline, (2) setting short term and long term goals related to targeted skills, (3) providing rewards and feedback to shape behaviour and provide assistance during difficult game situations, (4) progressive levels of difficulty and individualisation, matching task difficulty to player ability, and (5) providing choices supporting player autonomy. While a paucity of CBI in ASD have employed principles of this framework in developing their programs (Whyte et al. 2014), there is emerging evidence that this framework supports the transfer of social emotional skills to everyday contexts (Beaumont and Sofronoff 2008; Hopkins et al. 2011). While Whyte's framework entails guiding principles underpinned by both pedagogical and entertainment considerations, clearer illustrations in applying these principles to CBI are required.

Inclusive design practices provide one avenue for applying serious game principles to CBI, and increasingly researchers are collaborating with individuals with ASD during the design phase of serious games development (Constantin et al. 2017; Frauenberger et al. 2013; Parsons et al. 2011). This approach has been shown to enhance player engagement, and contributed to higher levels of adherence and content relevancy (Bernardini et al. 2014; Bossavit and Parsons 2016; Porayska-Pomsta et al. 2012; Schuller et al. 2013). Explorations of inclusive practices in ASD involving both professionals and youth with ASD reported these groups differed with regard to the relative importance they placed on varying components of the serious game framework (Parsons and Cobb 2014; Porayska-Pomsta et al. 2012). Professionals offered their expertise on pedagogical concepts and youth with ASD focused on motivational aspects of serious games, both areas equally critical in CBI development. Acknowledging the distinct expertise of both professionals and players in developing serious games promotes a more coherent gaming and learning experience for players with ASD. However to date, few CBI have targeted youth with ASD (Ramdoss et al. 2012), with limited consideration of how these interventions can improve the skills and functioning of individuals with ASD across the lifespan. If CBI is to be effective in improving the skills of older populations with ASD, the needs and learning styles of these populations must be further understood.

The present study, therefore sought to obtain the perspectives of youth with ASD and ASD-relevant professionals regarding the application of CBI for addressing emotion recognition difficulties. For this study, emotion recognition difficulties were specifically delineated given their critical role in underpinning broader social functioning in ASD (Trevisan and Birmingham 2016; Williams and Gray 2013). Perspective content was primarily guided by the serious game framework as outlined by Whyte et al. (2014). This framework was deemed most relevant given its consideration of both the pedagogical concepts and motivating elements of gaming, anticipated to be emphasised by professionals and youth with ASD respectively. Given the overlapping experiences of both participant groups, it was further expected that the groups would have differing, but complementary perspectives on CBI. Professionals may prioritise pedagogical elements while youth with ASD may emphasise more on the motivating aspects of the serious game framework.

## Methods

### Participants

Five focus groups and one interview were conducted involving 22 stakeholders of CBI targeting the emotion recognition skills of youth with ASD. Three focus groups comprised of youth with ASD (n = 11, one female) and two focus groups and one interview with experienced professionals (n = 11, five females). Youth with ASD had a clinical diagnosis of ASD as assessed by a multi-disciplinary team from a clinical service according to the Diagnostic and Statistical Manual of Mental Disorders fourth or fifth edition (American Psychiatric Association 1994; American Psychiatric Association 2013). Youth with ASD ranged in age between 13 and 24 years old ($M$ = 16.64 years, $SD$ = 2.95) (Table 1). ASD professionals ($M$ = 37.64 years, $SD$ = 11.44) included six occupational therapists, two educators, two psychologists and one speech pathologist (Table 2). All participants resided in Perth, Western Australia, were able to communicate in English and indicated their willingness to participate in a focus group. Given the targeted population of the proposed serious game was youth with ASD with average to high intellectual abilities, individuals with intellectual disability as assessed based on their current education were excluded from the study. Professionals were included if they were an allied health professional or educator with a minimum of 1 year experience in delivering interventions to individuals with ASD. Professionals were not required to have specific previous experience with CBI. The majority of the professionals either had experience in delivering CBI and/or were familiar with current games. Participants were recruited via social media (n = 2), a list of families previously expressing an interest in participating in research (n = 4), a technology interest group for youth with ASD (n = 5), and via personal and professional contacts (n = 11). Recruitment commenced in August 2015, ceasing in July 2018. Additional or new emerging themes were not identified in the third youth focus group (n = 4) and the second professional focus group (n = 5), underpinning the conclusion that data saturation was achieved (Morse 1995).

### Design

As the research aimed to elicit participants' shared perspective of the motivating aspects of a serious game targeting emotion recognition skills, focus groups were deemed the most appropriate data collection strategy. Focus groups generate data with an emphasis on the interactions between group members (Kitzinger 2008). The dynamic communication within focus groups supports the generation of new ideas through the exchange of perspectives and ideas between group members (Dewinter et al. 2016; Kitzinger 1994). Focus groups have been successfully employed with individuals with ASD (Cheak-Zamora and Teti 2014), are

**Table 1** Youth' characteristics

| Participant | Age (years) | Gender | Diagnosis | Education | Time spent on computer games (weekdays) | Time spent on computer games (weekends) |
|---|---|---|---|---|---|---|
| Youth 1 | 16 | Male | Autism | TAFE | > 5 h | > 5 h |
| Youth 2 | 24 | Male | Autism | TAFE | 1 | 1 |
| Youth 3 | 16 | Female | Autism, anxiety disorder, depression | Mainstream (year 11) | 3 | > 5 h |
| Youth 4 | 15 | Male | ASD | Mainstream (year 10) | 1 | 4 |
| Youth 5 | 16 | Male | Autism | Mainstream (year 11) | 3 | > 5 h |
| Youth 6 | 13 | Male | Autism | Mainstream (year 7) | > 5 h | > 5 h |
| Youth 7 | 16 | Male | Autism | Mainstream (year 11) | 3 | > 5 h |
| Youth 8 | 15 | Male | Autism | Mainstream (year 10) | 3 | > 5 h |
| Youth 9 | 14 | Male | Autism | Mainstream (year 9) | > 5 h | > 5 h |
| Youth 10 | 15 | Male | Autism, anxiety disorder | Specialist learning program (gifted and talented) | > 5 h | > 5 h |
| Youth 11 | 14 | Male | Autism, dysgraphia, selective mutism, developmental coordination disorder, anxiety disorder, encopresis | Mainstream (year 9) | < 1 h | > 5 h |

*ASD* autism spectrum disorder, *TAFE* Technical and Further Education College

**Table 2** Professionals' characteristics

| Participant | Age (years) | Gender | Profession | Years of expertise | Area in autism | Experience in computer based intervention |
|---|---|---|---|---|---|---|
| Professional 1 | 45 | Female | Psychologist | > 5 years | Clinical psychology, anxiety, peer mentoring | Involved in a reference group for the development of a computer based intervention for children with ASD |
| Professional 2 | 58 | Female | Education | > 5 years | Research, adult mentoring program | NA |
| Professional 3 | 27 | Female | Occupational therapist | > 5 years | Clinical occupational therapist, research | NA |
| Professional 4 | 43 | Female | Occupational therapist | > 5 years | Disability, vision impairment, research | NA |
| Professional 5 | 57 | Female | Education | > 5 years | Schools, supported living services, research | NA |
| Professional 6 | 29 | Male | Occupational therapist | > 5 years | Clinical occupational therapist, research | NA |
| Professional 7 | 35 | Male | Occupational therapist | > 5 years | Early intervention, school age therapy | Yes. Social emotional game for children with ASD |
| Professional 8 | 30 | Female | Occupational therapist | 3–4 years | Residential service, adult community, complex positive behaviour support | NA |
| Professional 9 | 28 | Male | Psychologist | > 5 years | Early intervention, school age therapy and adult positive behaviour support | NA |
| Professional 10 | 32 | Male | Speech pathologist | 1–2 years | Social skills, communication, behavioural and perspective taking skills | NA |
| Professional 11 | 30 | Male | Occupational therapist | 4–5 years | School age therapy, residential service, adult community | Yes. Videos or applications for independence skills |

beneficial in capturing the perspectives of those with lived experience (Bölte 2014; Cheak-Zamora and Teti 2014; Dewinter et al. 2016) and in refining CBI, ultimately enhancing the learning and engagement of users (Schuller et al. 2013).

### Discussion Guide

The serious game framework (Whyte et al. 2014) informed the focus group discussion guide. It aimed to obtain participants' perspectives on motivating storylines, strategies supporting goal-directed learning, meaningful rewards and feedback, game progression in terms of level of difficulty and individualisation, and choice presentation. Following piloting and feedback from two adults with ASD, a more structured approach to questioning was adopted, requesting specific examples rather than open ended questioning. For example, "What choices would you like to include in the computer game?" was rephrased to, "Can you list examples of the choices you would like to include in the computer game?" This variation to the traditional open ended approach was employed to accommodate the social communication difficulties of the participants with ASD (Cheak-Zamora and Teti 2014; Mazurek et al. 2015). The final discussion guides for the youth and professional groups are presented in Table 3.

To assist the youth with ASD in understanding the goals of the study and facilitate their comfort within the focus groups, they were provided with an information package prior to the focus groups. This contained both the discussion guide (Dilorio et al. 1994) (Table 3) and information on five currently available emotion recognition games compiled from published journal articles, video demonstrations and free/purchased versions of games. These games were the Secret Agent Society (Beaumont and Sofronoff 2008), JeStiMuLe (Serret et al. 2014), LIFEisGAME (Alves et al. 2013), Mind Reading (Golan and Baron-Cohen 2006) and Emotiplay (Fridenson-Hayo et al. 2017; Schuller et al. 2013). Information provided included a written and pictorial summary of the key features of each game inclusive of characters, environmental setting, narratives, goals or game tasks, choices, level progression, reward and feedback.

**Table 3** Discussion guide

| Question domain | Youth on the autism spectrum | Professionals |
|---|---|---|
| Introductory questions | Do you play computer games? If so, what types of games do/did you play?<br>What is/are your favourite computer game(s)? Tell me more about what you like about the game. [Provide prompt: stories, characters, environment, levels, feedback, rewards, difficulty, choices]<br>We are going to design a computer game to help teenagers and adults understand other people's feelings. We want to understand what you would like to include in the computer game so that it would be interesting and fun. [Provide draft storyline with visuals] | The aim of this focus group/interview is to gain your perspectives on what we should include to ensure that the computer game we will be designing to target emotion recognition skills, would be appropriate for teenagers and adults on the autism spectrum. [Provide draft storyline] |
| Motivating storyline | Can you think of some scenarios (or stories) that you would include in the game that would be interesting? [Prompt: any examples from the games you play or your previous experiences?]<br>Please give some examples of what characters you would like to be included in the computer game<br>Can you list some examples of what would be a good environment (or setting) for the game? | What scenarios (or stories) can we include that would be engaging and motivating for teenagers/adults on the autism spectrum to recognise other people's feelings? Provide some possible examples of the storyline for each of the scenarios (including examples from your previous experiences if possible)<br>What characters would be suitable to include in the computer game?<br>What would be a good environment (or setting) for the game? |
| Goal-Directed Learning | Can you think of some examples of the types of levels or milestones you would like to include in the game?<br>List some examples of what the player would need to do in order to achieve each level of the game | What are the stages needed to achieve emotion recognition skills? (initial skills, short term goals, long term goals)<br>What strategies can we use to ensure each of the goals (short term/long term) is achievable and motivating for teenagers/adults on the autism spectrum? |
| Rewards and feedback | Examples of good rewards that you could get in a game?<br>Please give examples on what would happen if (1) they achieve each level and (2) when they don't pass a level | What are the types of rewards that would be suitable/motivating for teenagers and adults on the autism spectrum in a computer game? (When a goal is achieved or a correct answer is given)<br>How can we best provide feedback to teenagers and adults on the autism spectrum? (for example when they achieved a goal/give a correct or incorrect answer) |
| Progression in level of difficulty and individualisation | List some examples of things you would like to see included in a game to make it more suitable for you. [Prompt: What is fun for you? What can we include when the game is too difficult?]<br>Can you think of examples of ways in which we can design each level so that it becomes more challenging as you go up a level? | What strategies can we put in place to personalise the game for each individual on the autism spectrum or how can we adapt the game to ensure it is suitable for the individuals on the autism spectrum?<br>How can we ensure that the learning experience is challenging yet achievable for teenagers/adults on the autism spectrum? |
| Provision of choice | Can you list examples of the types of choices you would like to see included in the computer game? | What types of choices should we consider or provide in the computer game for teenagers/adults on the autism spectrum? |
| Concluding questions | Do you have any other comments or things you would like to include in the game? | Do you have any other comments? |

### Procedures and Data Collection

Focus groups with the youth and professionals were conducted separately. The moderator commenced each group by introducing the aim of the study and obtaining permission for audio-recording. The youth focus groups commenced with 'warm-up' questions on participants favourite games, an approach previously used successfully to facilitate rapport building (Cheak-Zamora and Teti 2014). Following introductions, in an effort to stimulate discussions, all focus groups were presented with a draft visual storyline of a potential emotion recognition game, previously developed by a neurodiverse team of computer game developers. It described a robot navigating planet Mars with artificial intelligence technology containing emotion recognition abilities (Online Appendix). While questioning followed the discussion guide, participants were encouraged to spontaneously share their suggestions on methods for implementing the principles of the serious game framework in the proposed game. When necessary, requests for specific examples or follow up questions (examples in Table 3) clarified discussions. In the event of a participant dominating the discussion, the moderator employed strategies promoting a more balanced discussion such as prompting other participants to contribute, posing questions such as "Does anyone have something else to add?" or "What are your thoughts regarding…". Focus groups were audio-recorded and held in a meeting room on at a university campus, or at the professionals' workplace organisation lasting on average for 58 min, ranging from 38 min to 71 min. Groups were limited to a maximum of five participants, minimising the potential for participants with ASD to feel overwhelmed, and providing sufficient time for each participant to contribute. All focus groups were facilitated by an occupational therapist with 3 years' experience communicating with individuals with ASD, with an assistant taking field notes of the main points of discussion.

This study was approved by the [Curtin University] Human Research Ethics Committee [Ethics Approval Number: HR 52/2012]. Participants were informed of the aims of the study and given the opportunity to ask questions. Informed consent was obtained from the participants aged 18 years and above. For participants aged below 18 years, both assent and informed consent were obtained from the adolescents and their parents, respectively.

### Data Analysis

All focus group discussions were transcribed verbatim and crossed referenced with field notes taken during discussions. Data management was supported with NVivo 11 software (QSR International Pty Ltd 2012). Data was coded using directed content analysis (Hsieh and Shannon 2005) and guided by a framework approach (Pope et al. 2006). Transcripts were reviewed several times and coded based on the five components of the serious game framework (Whyte et al. 2014) with sub-themes emerging from an iterative process of revision and refinement. In addressing the core aspects of trustworthiness in this study (Lincoln and Guba 1985; Shenton 2004), credibility of the research findings was enhanced through a peer reviewed process, whereby the initial coding processes completed by the first author was reviewed by three additional researchers (second, third and fourth authors) (Beck 1993). The additional coders reviewed the transcripts, then discussed with the first coder to achieve an agreement of themes and the allocation of quotes. Any uncertainties or differences were resolved by discussion. Member checking was completed with all participants, whereby a written summary of the findings was provided a number of weeks following the groups. All participants confirmed that the findings reflected their perspectives. To address transferability and dependability of the findings, a detailed description of the participants' narratives, study design and data collection protocol is provided allowing readers to determine the relevancy of the findings to other contexts, enabling future replication of the study (Thomas and Magilvy 2011). Confirmability was supported through maintaining an audit trial of the decisions undertaken during the analytical process via journaling (Shenton 2004).

## Results

The youth with ASD and professionals' perspectives emphasised different components of the serious game framework. While the youth emphasised the importance of a 'motivating storyline', professionals focused on 'goal directed learning' and generalisation of skills to everyday contexts.

### Motivating Storyline

The youth with ASD emphasised the importance of a serious game being underpinned by a motivating storyline. From their perspective, an engaging game encouraged players to continue playing. Motivating storylines included a "game environment with variety", "dilemmas" and "Easter eggs" (a hidden message or surprise). Professionals discussed the value of adding "dilemmas", emphasising embedding "real life scenarios" within the narrative of a serious game.

#### Game Environment with Variety

The youth preferred "different themes or environments", "different series" or a multi-dimensional game world as they progressed through the storyline. A variety of characters or "non-playable characters" also added depth and "realism" to the game environment.

#### Dilemma

The youth with ASD preferred games centred on a "dilemma", or a "massive overarching problem", with "obstacles", "conflicts" or "serious situations". They described the potential role that a "companion" or "enemy" character could play in creating a dilemma within the gaming environment. The companion character was a "generic" character with whom the player could form an emotional connection, or a character they could "relate to". The "enemy" was an antagonist character who "created tension" central to gameplay.

Professionals described adding dilemmas or "consequences" within the game narrative as an "age appropriate" feature for youth with ASD. One professional described including "depth" and "detailed backstories" of a character as meaningful, allowing the youth with ASD to emotionally connect with a character.

#### Hidden Messages and Side Jokes

The youth discussed hidden messages, within the narrative of the game as encouraging players to continue playing, and providing an element of surprise. "Easter eggs" as an example, created the opportunity to include "jokes" with meaningless "hints and secrets" or comical elements.

#### Real Life Scenarios

Professionals emphasised that the central challenge of CBI should be the generalisation of learnt skills to daily functioning. Given this, "real life scenarios" with "clear links" between learnt skills and "normal environments" were prioritised.

While professionals acknowledged that futuristic themes are motivating for the individuals with ASD, they emphasised the importance of including typical human interactions and linking social narratives with "major life areas", such as "employment" or "dating", providing "useful and tangible" outcomes for the individuals with ASD. Youth also provided examples focused on responding to different social situations. This includes incorporating 'realistic' characters or scenarios in the game assisting players to "bridge real life aspects". One example included "interacting and integrating" with various characters within the gaming environment through situational challenges, such as managing and resolving "conflict".

### Goal Directed Learning

The youth with ASD focused on the importance of ensuring that the game goals within each level were fun. Both participant groups further outlined a number of learning goals relevant to understanding and responding to emotions.

#### Gaming Goals with Clear Outcomes

The youth described the importance of having both long and short term goals in the game, which were clear with regard to the tasks involved and outcomes achieved. They discussed concrete outcomes or "game missions" relating to survival, territorial advances and scavenging or collecting resources (Table 4). Exemplar quotes from the youths relating to survival, territorial and scavenging goals are presented in Table 4.

#### Understanding Emotions

Professionals emphasised the need for "concrete" approaches in addressing emotion recognition skills of youth with ASD. A three stage heuristic for understanding emotions, which may be integrated into the CBI was suggested. This included the stages, "what does it feel like?", "what is going on?" and

**Table 4** Exemplar quotes from the adolescents and adults with ASD on motivating gaming goals

| Themes | Exemplar quotes |
|---|---|
| Survival | "You could shoot the enemies from the sky? [or] from space with…a giant, satellite laser cannon." (Youth 6)<br>"You [are] on this desert island…and you pretty much have to survive,…you have to hunt [and] collect resources." (Youth 2) |
| Territorial | "You and a team try to take over another area and the more people there are in that area, you have taken over and then you move into another one [and] another. So more like a territorial mini game." (Youth 7) |
| Scavenging | "While the robot is going back to Earth, the ship went into pieces and landed all over Earth…so he goes around the world…to find all the parts of the [ship]." (Youth 11)<br>"So like, everybody's like its ships are just aimlessly wandering around scavenging and all aggressive towards each other…You could feel like there is going to be some sort of like uproar to try and grab some extra supplies." (Youth 7) |

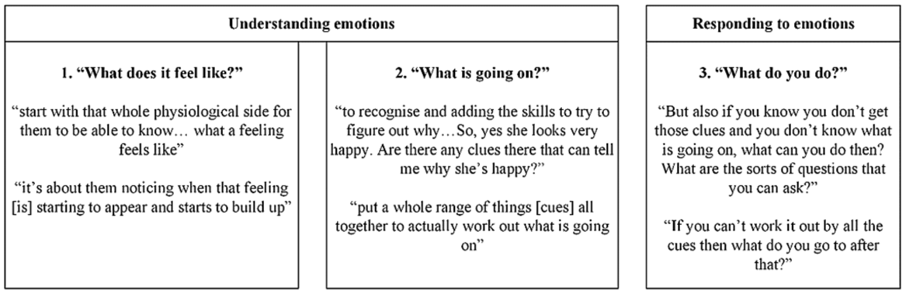


**Fig. 1** Data analysis of professional focus groups revealed two main goals, with a three stage schema for an emotion recognition serious game for youth with ASD

"what do you do?", summarised in Fig. 1. The first stage, supported "self-reflection" on "what" an emotion feels like on a personal "physiological" level. The second stage required players to identify emotions by integrating clues from the "face", "tone of voice", "body" and the "environment". The third stage highlighted the importance of generating appropriate responses in order to connect goals to "ultimate outcomes", motivating individuals with ASD to understand the benefits of emotion recognition goals.

#### Responding to Emotions

Professionals emphasised the importance of discouraging "rote learning", and promoting strategies such as considering contextual cues and the appropriateness of responses within varying contexts, including communicating assertively. As several professionals reflected:

> I remember a guy…he was at a funeral and he saw people sad. So he did recognise that they were sad but then he started telling jokes because he wanted to make them happy, so is that socially appropriate? (Professional 10)

Professionals also encouraged "problem solving" via a "toolbox" of responding strategies which could be used to "repair or resurrect difficult situations".

### Rewards and Feedback

The youth and professionals agreed on using "continuing storyline", "upgrades" and "collectables" in providing opportunities to meaningfully reward players. The youth suggested including "bonus features" as another motivating reward feature. Both groups suggested feedback could be provided via "hints and tips" and "natural feedback". The youth added that feedback could also be provided through providing "second chances", or "visual feedback". Professionals proposed "peer-to-peer feedback" as another option. Exemplar rewards and feedback as well as supporting quotes are detailed in Table 5.

### Progression in Level of Difficulty and Individualisation

The youths and professionals suggested "scaffolding skills" and "emotion recognition progression" as a means of ensuring an appropriate level of difficulty for players. Professionals suggested implementing "auto correct" and "multi-choice options" as useful individualisation features to support players during a difficult game task.

#### Emotion Recognition Progression

In increasing the level of difficulty of emotion recognition tasks, the youth and professionals suggested progressing to "more complex" and "less obvious" emotions, and the inclusion of tasks requiring the recognition of emotions through "voice" and "body language".

Professionals discussed slowly incorporating emotions requiring the players to consider "hidden emotions", recognising emotions across contexts, and generalising emotions recognition skills across gender and ages. Professionals discussed grading the speed as a strategy to increase the difficulty of the game, in relation to the "time of exposure" of emotions or "flashing" facial expressions for briefer periods to increase difficulty.

The youth suggested increasing the complexity of "options" and social encounters via the inclusion of "difficult" or less cooperative characters.

> …have multiple different people that you could use to get to the next stage, you can have like one [who] is

**Table 5** Suggested rewards and feedback for an emotion recognition serious game identified by the youth and professionals

| Reward/feedback | Definition | Reward/feedback examples | Exemplar quotes |
|---|---|---|---|
| Continuing storyline | Motivating storylines or natural progression in a gaming narrative | New motivating scenarios or natural responses from characters | "Yeah, the rewards are a continuation of the story. If you have like a heavily story based game, …the thing that drives the people to keep playing it, is that they want to get to the end of the story." (Youth 1)<br>"Say you need to catch the bus and you [see] the person selling the tickets crying…you have to ask them if they are okay to buy the ticket to get on the bus, [after that] you can progress and try the next level." (Professional 3) |
| Bonus features | Special features or additional challenges which may be obtained | Side plots, mini stories, new levels, downloadable content | "That could be a bonus feature…you beat the game, then you [have a] new game [with] more enemies and different worlds" (Youth 5) |
| Upgrades | Advancing in character's abilities | Special features or power advancing character's abilities or personality profile | "Energy…like electricity energy…or maybe a special ability that gets unlocked! That's really cool! Like you can jump extra high, let out a sonic beam or something?" (Youth 2)<br>"I've seen games where…it builds a profile of you as a person…You have strengths in courage if you…stand up to situations…or those who always come to a fair solution [gets] honour…You would build points in those areas based on the options you choose." (Professional 7) |
| Collectables | Extra trinkets or items | Points, coins, cars, clothing options, materials useful for defence such as fuel, ammo, weapons and shields | "If it is [an] online game, [when] you reach level 10, you can earn 10 dollars from the real world, maybe." (Youth 9) |
| Hints and tips | Information guiding the player to the preferred gaming pathway or choice | Hints and tips can be presented in a tutorial level, textual, visual or verbal format from another character | "In the game…going to the past…where you meet an old man…and then he would give you some tips and some resources." (Youth 6)<br>"You're working with a robot builder and he is grumpy and he does not want to do this for you…Your options are to ask him nicely and explain why you need it or…telling him he has to because he is getting paid. You choose the latter…a little tip pops up. It goes you earned x points for this because….did you know that people generally respond better when you do this." (Professional 7)<br>"One tip every ten, [or] fifteen minutes of game play" (Professional 11) |
| Second chances | Opportunity to reattempt the task again | Checkpoints or an auto saving feature | "Maybe you [can] back off for a bit, and then go and talk to some other people…after a time period, you can come back and ask them again?" (Youth 3) |

**Table 5** (continued)

| Reward/feedback | Definition | Reward/feedback examples | Exemplar quotes |
|---|---|---|---|
| Visual feedback | Visual cues of progress using progression bars | Life, health or happiness bars | "You could have a 'talk' bar on the top? So if you do something wrong, their happiness level drops down a bit…if she gets upset, you [do] whatever you need to, and [the bar] would go 'green' and then 'yellow', 'orange', 'red'." (Youth 3) |
| Naturalistic feedback | Naturalistic reactions from the game character and/or incorporating natural self-regulation elements | Natural emotion expressions or responses, sleep and wake cycle to prompt players to rest during the game | "Sims® is also good because it sort of teaches you…if you have your Sim, and you have some random person who shares your interest, but you don't go up to the random Sim you've never known, and give them an enormous hug. They don't like that!" (Youth 3)<br>"You say to him 'Hi Jim, how are you?' and he says, 'Oh, not very good today' and you have to respond in a way that he changes his response…it is [a] natural feedback response." (Professional 3)<br>"Can you incorporate…natural activities of daily living, like a sleep cycle? You know your character is fatigued… and you have to take a break…switch off the game in order for you to recuperate" (Professional 9) |
| Peer-to-peer feedback | Involve a peer to provide feedback during the game | Friend or mentor | "They can get another peer who they are quite close with and wants to help them to play the game, as well. And the peer gives them feedback." (Professional 3) |

> really difficult to convince…and the other one is really easy. (Youth 3)

#### Scaffolding Skills Via Gameplay

The youth proposed staging the challenges from “easy, medium to hard” as a means of increasing the level of difficulty of the game, promoting the scaffolding of skills. Examples of this strategy included modulating the “speed”, reducing the amount of support or “clues” and slowly introducing “harsher environments” and “obstacles”, delaying players’ progression to the end goal.

Professionals emphasised scaffolding new skills in a “safe space” through introducing “sub-categories” or “mini-games” for players to practice a skill prior to progressing to the next stage:

> Someone can fail but it has to be in a safe space, the opportunity to practice again,…it might be that you do an activity or a sub-game…to practice this skill before doing the test…because if you just go straight in, [if they] fail. They’ll disengage. (Professional 8)

#### Support Strategies

Professionals described grading the level of support through progressively moving from “concrete” to “more subtle cues” as a support strategy for increasing the level of difficulty. One professional suggested utilising a variety of cues:

> You might do a visual cue first…on the screen. So it might highlight something to investigate…You could do more subtle environmental cues…often they’ll use lighting to draw your attention to a certain area. (Professional 6)

“Auto-correct” and “multi-choice options” was described by the professionals as a support feature in ensuring the game was achievable for players. “Auto-correct” was discussed as an automatic in-built system which adapted to the players progress, enabling players to “retry the level”. Professionals mentioned providing “something to choose from” as a strategy to reduce player’s frustration during the game. As one professional stated,

> “I think having options so that they don’t actually have to come up with them [emotions] themselves, [and] think about that emotion out of nowhere.” (Professional 1)

### Provision of Choice

The youth described choices as an integral feature in engaging players in the game, even though some choices may result in the “same outcome” and may be “pointless”. They described identified “selecting own rewards” as a motivating choice feature. Youth and professionals similarly identified choices relating to game pathways and characters, categorised under the sub-themes “it’s not linear” and “character choices”.

#### Non-linear Gameplay

The youth preferred non-linear games as they provide “a few directions”, “two or three different pathways” or “more than one way to do something”. “Sandbox” was an example provided of a non-linear game, an open gaming world restricted by boundaries, allowing players to control their gaming pathways.

> Sandbox! It’s not linear. You can go here or there and you are only restricted…by the ocean or something. You can’t go beyond the shoreline. (Youth 2)

Professionals discussed that allowing choices in gaming pathways would promote motivation, instilling a sense of “control”, providing opportunities for players to exercise their “creativity” and personalise their gaming experience. While professionals saw non-linear pathways as beneficial they also suggested that players may at times deliberately choose the “wrong” pathway for comedic reasons, reducing emotion recognition learning opportunities. One professional suggested integrating pathway responses with experience points, motivating players to select appropriate responses:

> You get experience points,…every time you do a little thing right but then you get even more when you do achieve a level,…that concept reinforcement…I guess it’s trying to make sure all the incorrect responses are not too rewarding or too reinforcing. (Professional 9)

#### Selecting Own Rewards

Youth suggested allowing players to choose between different rewards, possibly linked with strategies to complete upcoming game missions.

> …You’ve got to choose between what is more important…Like what you need to do to defend yourself. Or if you need more…fuel, in order to actually do missions…And give the player a specific set of weapons and shields. (Youth 7)

#### Character Choices

The youth mentioned character choices in relation to choosing between “multiple characters”, “customising” their "looks", "abilities", and having "someone to control", as seen in many "role playing games".

> You [could] select different versions of that character…So say your character…has some sort of hammer cannon [or] a different version of that character with… a rail gun? (Youth 6)

Professionals mentioned players would be motivated to "personalise what their [character] looks like", "choose their own person [character]" or have the "power to create somebody in the game", including deciding the character's strengths and weaknesses. One professional suggested:

> If you choose to be a wizard for example…you are fantastic at magic but you are not good in combat… You can make him look however the way you want,… male or female,… hair colour, freckles, size of their nose, ears…So it is that immediate personalisation. (Professional 11)

## Discussion

This study aimed to obtain suggestions from youth with ASD and professionals on methods to practically apply the five serious game principles outlined by Whyte et al. (2014). The youth and professional groups held differing views with respect to 'motivating storyline' and 'goal-directed learning', but had complementary suggestions for 'rewards and feedback', 'progression in level of difficulty' and 'choices'. Findings from this study offer insights towards potential design features of future CBI in ASD, with particular relevance to developing age appropriate gaming content for youth with ASD.

The youth emphasised the importance of improving the motivational experience of serious games, via strategies such as immersive narratives with unpredictable elements within changing game environments. These suggestions were somewhat in contrast to reports characterising ASD in everyday environments, highlighting that unpredictability can often provoke feelings of anxiety (Carrington and Graham 2001; Müller et al. 2008). CBI provide an opportunity for players with ASD to challenge their emotion recognition skills, while receiving parallel supports within a safe and autonomous learning environment (Golan and Baron-Cohen 2006; Kapp 2012). Youth in this study highlighted the importance of incrementally increasing the difficulty of gaming tasks and matching gaming demands with player's skills, as strategies facilitating player engagement (Admiraal et al. 2011).

Professionals in this study emphasised the importance of supporting the generalisation of skills, via embedding naturalistic scenarios and feedback. It is likely these recommendations were underpinned by their recognition of the propensity for individuals with ASD for concrete thinking and their preference for rule based systemising (Baron-Cohen et al. 2003; Minshew et al. 2002). In considering the learning styles of youth with ASD, the professionals recommended embedding realistic gaming content with tangible connections to everyday situations, facilitating the generalisation of outcomes. Challenges in promoting the generalisation of skills learnt during social emotional CBI to everyday life are evident in current research, with few studies reporting the translation of learnt skills (Ramdoss et al. 2012). Further attention to the application of strategies supporting the generalisation of skills learnt during social emotional CBI to everyday environments, including integrating serious game principles (Whyte et al. 2014), combining CBI with mentoring (Golan and Baron-Cohen 2006; Russo-Ponsaran et al. 2014) or real world related tasks (Beaumont and Sofronoff 2008) would likely improve generalisation outcomes.

Findings of this study offer insight into implementing the serious game framework from the perspective of professionals and youth with ASD. However, consistent with findings of previous research these groups differed with regard to the relative importance they placed on varying components of the serious game framework (Parsons and Cobb 2014; Porayska-Pomsta et al. 2012). This highlights the importance of considering both perspectives during the design of serious games, with professionals offering their expertise on pedagogical concepts and youth with ASD focusing on motivational aspects of serious games. Given the complexity of merging perspectives in developing serious games, game developers may be often tempted to prioritise the perspectives of professionals, compromising motivating elements (Goh et al. 2008; Malinverni et al. 2017; Parsons and Cobb 2014). Acknowledging the distinct expertise of both professionals and players in developing serious games promotes a more coherent gaming and learning experience for individuals with ASD. Further research is required to explore more holistic techniques for integrating the perspectives of professionals and individuals with ASD (Benton et al. 2012; Frauenberger et al. 2011; Malinverni et al. 2017; Porayska-Pomsta et al. 2012).

The youth with ASD in this study were greatly engaged and invested in the topic of discussion. This is not surprising given that individuals with ASD spend significant amounts of time in computer based activities (Mazurek et al. 2012). Providing briefings to the youth with ASD on the aims of a social emotional serious game was key in focusing their ideas on the educational goals of the game. This strategy was previously proposed as a model for involving various stakeholders in serious game design (Khaled and Vasalou 2014), providing an opportunity to leverage the expertise of different groups in designing serious games. Further inclusive game development approaches could explore supplementing all end-users with knowledge on the educational and motivational domains of a serious game to integrate differing perspectives.

### Suggestions for Future Social-Emotional Serious Games

The perspectives of the youth and professional groups in this study is consistent to Whyte et al. (2014) Serious Game framework, specifically emphasising the importance for a 'motivating storyline', 'rewards and feedback' and 'choices'. The youth's focus groups expressed a preference for immersive narratives with a clear end goal, rather than as an overarching theme or sub-narratives. Secret Agent Society©, although designed for children with ASD, is an example of a game utilising a long-term narrative with a clear goal (e.g. Beaumont and Sofronoff 2008). Incorporating narratives throughout the game offers a suggestion for future CBI to contextualise and create meaningful learning experiences for youth with ASD. Additionally, both participant groups in this study reiterated the importance of including naturalistic social goals with realistic narrative progressions in CBI as a means to stimulate real life scenarios and ultimately facilitating generalisation. Virtual reality interventions simulating real employment scenarios (e.g. Kandalaft et al. 2013) or game characters responding naturally to the players' responses (e.g. Bernardini et al. 2014) have shown some promise in improving social emotional skills, highlighting the importance of naturalistic goals and feedback in CBI. Finally, the findings of the present study indicate that players with ASD are motivated by choices supporting autonomy and creativity, views consistent with previous research (Mazurek et al. 2015). Existing CBI in ASD support autonomy of players through providing options in selecting the difficulty of game tasks (e.g. Golan and Baron-Cohen 2006; Hopkins et al. 2011), but are limited with regard to the depth of gaming environment. From the participants' perspectives, we suggest future CBI for youth with ASD facilitate both the autonomy and creativity of players by placing them in the role of game characters, and providing at least two gaming pathways relevant to the learning goals and narratives within the game (Patall et al. 2008; Przybylski et al. 2010).

Analysis of the perspective of youth and professionals in this study point to suggestions for improving the motivational and learning features of future social emotional serious games, specifically games targeting youth with ASD. Consultations with both these stakeholders groups enabled further operationalisation of the five serious game principles described by Whyte et al. (2014) and specified their application to an emotion recognition serious game targeting youth with ASD. These are outlined in Table 6. While the focus of this study was specifically on emotion recognition serious games, several suggestions provided in this study are easily applicable to serious games targeting other skills. The general consensus from both youth and professional groups were highlighted embedding immersive narratives with a clear end goal, naturalistic learning goals and feedback, and autonomous control of gaming pathways. Further review and refinement of these proposed serious game features through subsequent co-production processes is essential, as outlined by those developed by the Cooperative Research Centre for Living with Autism (2016) in Australia. This includes actively involving key stakeholders in development meetings and usability testing, enabling tailoring of therapeutic content to the needs of the target population and ultimately promoting engagement (Malinverni et al. 2017; Porayska-Pomsta et al. 2012; Schuller et al. 2013). Further research could evaluate the efficacy of CBIs incorporating serious game features in remediating social emotional difficulties of individuals with ASD.

### Limitations

The findings of this study must be interpreted within the context of its limitations. While the sample size was small and probably selective by motivation to participate, saturation was assumed for the youth as additional emerging themes were not identified during the analysis of the third focus group (Morse 2015). The evidential gender bias of the study sample necessitates consideration of the fact that the serious game features described may not represent the views of females with ASD, thus direct comparison between the genders was not possible in this study. Previous reviews reported differences in experiences between male and females diagnosed with ASD (Halladay et al. 2015; Lai et al. 2015). Future CBI research could further explore the perspectives of females with ASD and investigate potential gender differences in serious game preferences. While strategies were utilised to encourage participants to express their perspectives, this study was limited to participants with ASD with higher expressive communication skills, and may not have captured the views of those more uncomfortable with group discussions and limited verbal skills, a population group which possibly have differing gaming preferences. Future studies could consider alternative approaches to obtaining perspectives of individuals with ASD, including providing the option to complete an individual interview, written report or Q-sort methodology (Scott et al. 2015). The results of this study provide a synthesis and description of the suggested motivating features of a potential emotion recognition serious game from the perspectives of end-users and professionals, but did not prioritise specific emotions for inclusion in such a game as previously conducted with

**Table 6** Perspectives of the professionals and youth and suggestions for applying serious game principles in an emotion recognition game

| Serious game principle | Professional's perspectives | Youth's perspectives | Suggestions for application |
|---|---|---|---|
| Motivating storyline | • Real life scenarios<br>• Dilemma | • Game environment with variety<br>• Dilemma<br>• Hidden messages and side jokes | • Embedding narratives throughout the entire game, rather than as an over-arching theme or sub-narratives<br>• Providing variety within the game environment such as themes and characters<br>• Including game characters impeding player's game progress<br>• Including random or surprise game elements<br>• Including relevant real life themes relating to major life areas |
| Goal-directed learning | • Understanding emotions<br>• Responding to emotions | • Gaming goals with clear outcomes<br>• Responding to emotions | • Providing players with an understanding of a clear end-goal at the start of the game<br>• Addressing emotion recognition learning (identifying or responding to a specific emotion) via communicating with game characters<br>• Adding goals surrounding understanding the meaning of emotions across a variety of contexts and providing strategies to problem solve different situations |
| Rewards | • Continuing storyline<br>• Upgrades<br>• Collectables | • Continuing storyline<br>• Bonus features<br>• Upgrades<br>• Collectables | • Utilising narratives as a reward<br>• Including bonus features such as side plots or mini games<br>• Upgrading the character's abilities based on their gaming performance<br>• Allowing players to collect different objects as rewards, possibly relating to the larger game narrative |
| Feedback | • Hints and tips<br>• Naturalistic feedback<br>• Peer-to-peer feedback | • Hints and tips<br>• Naturalistic feedback<br>• Second chances<br>• Visual feedback | • Presenting 'hints and tips' through dialogues with characters or visual progress bars<br>• Setting limits for re-attempting challenging gaming tasks to avoid disengagement from repeating game tasks<br>• Including game characters responding naturally to player's responses and incorporating natural self-regulation elements such as a sleep cycle<br>• Involving a mentor or peer to provide ongoing support |
| Increasing levels of difficulty and individuation | • Scaffolding skills via gameplay<br>• Emotion recognition progression<br>• Support strategies | • Scaffolding skills via gameplay<br>• Emotion recognition progression | • Progressively introduce complex emotional content, e.g. basic to complex emotions the amount of challenges and slowly introducing emotions across context<br>• Provide mini games for players to practice skills prior to progressing to challenging levels<br>• Withdrawing the frequency of supports and cues<br>• Including automated systems monitoring the players' progress, allowing adaptations to the amount of reattempts and failed trials<br>• Introducing multi-choice gaming format |

**Table 6** (continued)

| Serious game principle | Professional's perspectives | Youth's perspectives | Suggestions for application |
|---|---|---|---|
| Choice | • Non-linear gameplay<br>• Character personalisation and development | • Non-linear gameplay<br>• Selecting own rewards<br>• Character choices: visual appearance or abilities | • Including game mechanics allowing non-linear game pathways or options for completing gaming tasks in several sequences<br>• Incorporate experience points, motivating players to select appropriate responses, i.e. players obtain higher points for appropriate responses<br>• Providing different reward options<br>• Allowing players to adopt the role of a specific game character and autonomously control the character's pathways<br>• Allowing options to personalise the character's appearance or abilities |

children with ASD (Fridenson-Hayo et al. 2017). Further research is required to determine the most salient emotions to include in a game from the perspectives of youth with ASD and professionals.

## Conclusion

This study presents a consultative approach aimed at obtaining design suggestions from the perspectives of youth with ASD and professionals. The five serious game principles outlined by Whyte et al. (2014) were utilised in ensuring that the design suggestions were framed within the pedagogical and motivational theories for a serious game. The results illustrate the potential application of the serious game framework, including suggestions in merging the differing and complementary perspectives of professionals and youth. Further research is necessary in refining the design suggestions and validating its effectiveness to improve social emotional skills.

**Acknowledgments** The researchers would like to extend our gratitude to youth on the autism spectrum and the professionals for the time and effort taken to participate in this focus group as well as Melissa Black, who assisted in data collection and Greg Lynn who provide assistance in data transcription.

**Author Contributions** JT conceptualised and designed the study, involved in data collection, analysed and interpreted the data, and contributed to drafting the article. MF conceptualised and designed the study, interpreted the data, and revised the draft. NC interpreted the data and critically revised the draft. SB conceptualised and designed the study, revised and critically contributed to the intellectual content of the article. SG conceptualised and designed the study, involved in data collection, interpreted the data and critically revised the article. All authors contributed to and have approved the final manuscript.

**Funding** This research is supported by the Cooperative Research Centre for Living with Autism (Autism CRC) [Project Number 3.032RS], established and supported under the Australian Government's Cooperative Research Centres Program. JT is supported through an Australian Government Research Training Program Scholarship.

## Compliance with Ethical Standards

**Conflict of interest** The authors declare that they have no conflict of interest. SB reports no direct conflict of interest related to this article. SB discloses that he has in the last 5 years acted as an author, consultant or lecturer for Shire, Medice, Roche, Eli Lilly, Prima Psychiatry, GLGroup, System Analytic, Kompetento, Expo Medica, and Prophase. He receives royalties for text books and diagnostic tools from Huber/Hogrefe, Kohlhammer and UTB.

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# Chapter 4 : Introduction to eye-tracking methodology and visual attention in autism

# Interim Summary and Preface

The meta-analysis in Chapter 2 sought to examine the potential impact of serious game design (1) in enhancing the effect of social emotional CBI for autistic individuals. The meta-analytic findings revealed a moderating influence of serious game design principles in targeting social emotional outcomes. More specifically, greater serious game application was associated with improvements in distant generalisation and transferability outcomes. Since generalising skills to real world context is an integral outcome for social emotional interventions (2), the meta-analytic findings bolster the relevance of implementing serious game design principles in the development of social emotional CBI for autistic individuals.

Given the empirical evidence of serious game application in improving social emotional generalisation outcomes, Chapter 3 aimed to obtain perspectives from key stakeholders regarding the application of the design principles of the serious game framework for a social emotional CBI for autistic adults. Autistic youth and autism professionals outlined key recommendations to practically apply the five serious game principles outlined by Whyte, Smyth (1). While the findings of Chapter 3 reiterated the value of applying the serious game framework, the autistic youth and autism professionals emphasised the importance of embedding explicit strategies to support better generalisation of skills to everyday environments. They provided several suggestions to integrate naturalistic elements within the CBI, and further recommended implementing mentoring components to implicitly promote better generalisation of skills. Embedding mentoring approaches have been shown to strengthen opportunities for autistic individuals in generalising learnt skills beyond the intervention environment (3, 4).

Taken together, the findings from Chapter 2 and 3 highlighted two key strategies for facilitating the generalisation outcomes of social emotional CBI, mainly embedding serious game design features and facilitator mediated approaches. Given the paucity of social emotional interventions targeting autistic adults (2), the present thesis adopted an incremental approach to understanding the key strategies for facilitating social emotional generalisation outcomes. Specifically, the present thesis focused on developing facilitator mediated components and evaluated the utility of embedding this approach with an existing social emotional CBI for autistic adults. The review presented in Chapter 2 found that only three social emotional CBI were evaluated with autistic adults, representing 21% of the studies included in the review. Amongst the three social emotional CBI, the Mind Reading program (4) was selected as the most appropriate CBI to be used in conjunction with a facilitator mediated approach given that it was the most recent and only commercially available CBI for autistic adults.

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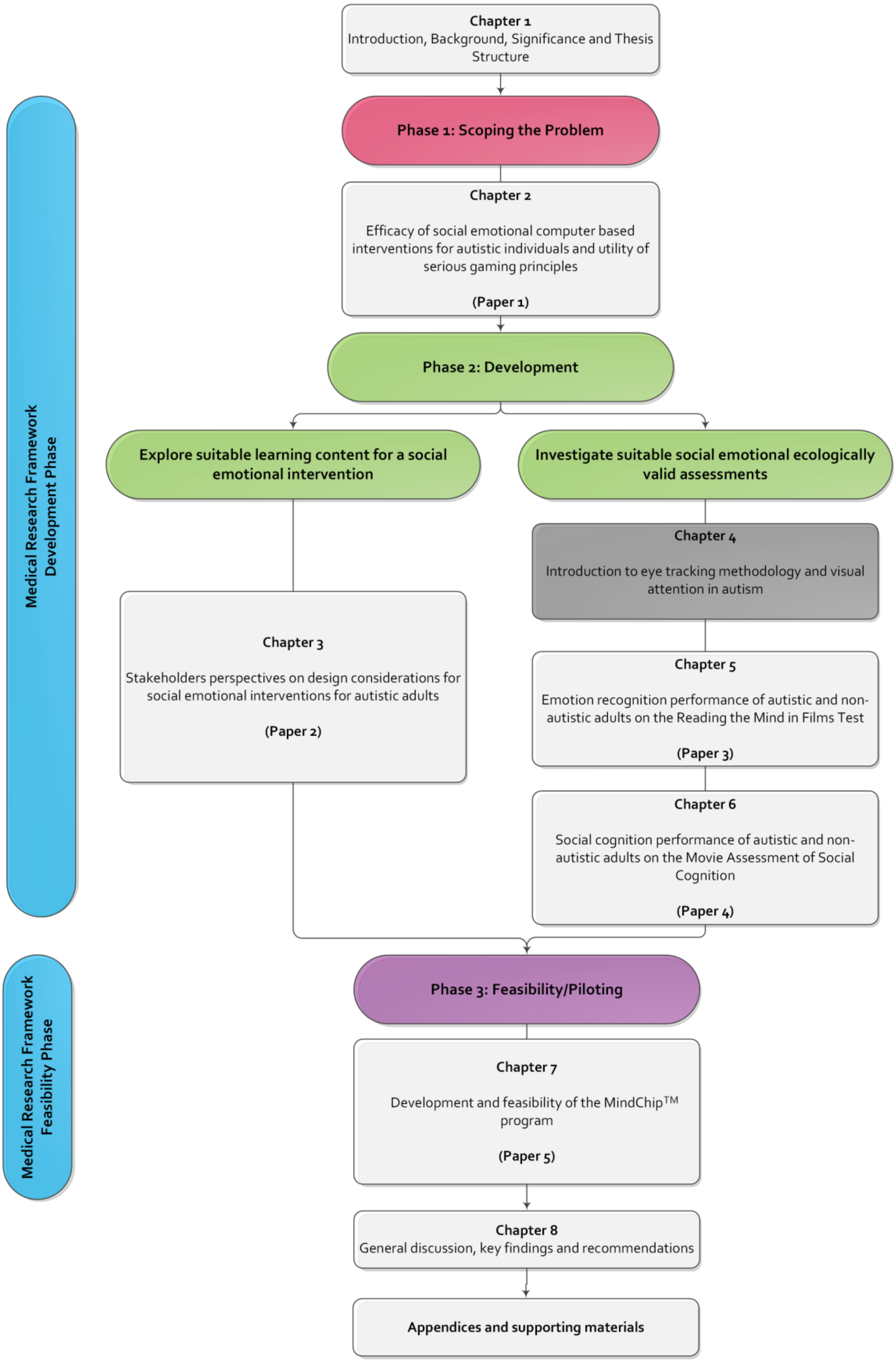


**Figure 4.1. Thesis structure Chapter 4.**

# Introduction to eye-tracking

The visuo-oculomotor system is a complex neural mechanism for gathering and processing visual information from the external environment (1). High acuity visual information is restricted to a small visual field, a region also known as the central foveal vision (2). This region is approximately $2^{o}$ in diameter and encompasses only $1/4000^{th}$ of the retina (3). Visual resolution rapidly diminishes outside of the fovea (2). To acquire detailed visual information, the eyes compensate by continuously relocating the fovea to new locations approximately three times per second (4). Given the rapidness of these movements, these processes often occur unconsciously. Therefore, eye movements represent an active behavioural strategy for acquiring relevant visual information, providing insights into the visual and cognitive processing of the individual (5).

Eye-tracking technology is a nonintrusive system for measuring eye movements, providing useful insights into the direction of visual attention during the processing of social information (6, 7). Eye-tracking typically records both saccades and fixations, resulting in a visual pattern defined as a scan path (8). Saccades are defined as ballistic eye movements, and constantly redirect the fovea to areas of interest (9). Saccadic eye movements occur at high velocities, limiting visual sensitivity and suppressing the acquisition of visual information (10, 11). Analysing shifts in saccadic movements provides insights into the reallocating of perceptual attention (12). Fixations describe gaze maintenance in relatively stable position, typically for approximately 200-400 milliseconds (9, 13). During fixations, the foveal vision is activated, allowing detailed processing of visual information (4), providing insights into overt visual attention (14, 15).

Eye-tracking measurements are commonly categorised into *temporal*, *spatial*, and *count* scales (16, 17). Temporal scales provide information relating to the duration of visual processing, including total time spent on specific regions. Longer fixation duration typically indicates higher levels of engagement and a level of interest towards the visual information (18). Spatial scales relate to measurements of space, including distance between saccades and scan path patterns, providing insights into patterns of viewing visual information (18). Count scales describe the frequency of fixations, providing information about the significance of the targeted location. Fixation counts are reported to be closely associated with fixation duration measures. Given that fixations indicate detailed visual information processing (4), temporal eye tracking measurements, specifically fixation duration outcomes were reported in this thesis.

# Visual social attention in autism

Visual social attention refers to preferential orientation and attention to people, including faces and eye regions (19, 20), and more broadly regarded as a gateway for processing social emotional information (15). Given this, emergent research is implementing eye tracking based methods to gain further understanding into the mechanisms underlying the social emotional processing difficulties of many autistic individuals (21, 22). A wide variety of experimental paradigms have been employed in investigating the visual social attention of autistic individuals, including paradigms measuring gaze cueing, change detection, attention shifting, and eye movements (23, 24). Classic paradigms of visual social attention are largely underpinned by measures of accuracy or response time measurements (25). However, restricting attentional measurements to keyboard responses are likely insufficient in enabling understanding of the dynamic complexities of social attentional processes. Paradigms such as eye tracking are more likely to support a more sophisticated and nuanced understanding of autistic individuals behavioural patterns and abilities in processing social information (22).

To date, eye-tracking studies for exploring social attention in autism have largely employed stimuli presenting naturalistic static images or dynamic social interactions with or without audio input (23). Studies using static stimuli commonly report inconsistent findings, with some reporting autistic individuals as demonstrating reduced gaze to the eye regions of the face (26, 27), while others report no group differences between autistic and non-autistic individuals (28, 29). Reduced ecological validity of static stimuli is discussed as one factor potentially contributing to these inconsistent findings (21). Dynamic stimuli depicting ecologically valid social interactions have demonstrated higher sensitivity in eliciting differences in social emotional performance (21, 30). However, a previous review revealed a paucity of research examining the visual social attention of autistic adults, finding only three studies employing dynamic stimuli with naturalistic social interactions (22). This rationale underpinned the choice of dynamic ecologically valid social emotional assessments for investigating the social emotional performance of autistic adults in the studies presented in this thesis.

Previous eye-tracking reviews examining social attention have reported that autistic individuals are more inclined to avoid socially salient areas, fixating less on the faces during the processing of social emotional scenes (22, 31). Avoidance of socially salient regions appear to be increasingly prominent during stimuli with higher social content, suggesting that the number of characters in a scene may impact on the social attentional processes of autistic individuals (31). Fine grain analysis of facial regions revealed that autistic adults typically demonstrate reduced eye fixation duration (32, 33). Preferential mouth gaze findings are less consistent, with studies reporting both presence and absence of this phenomenon in autistic adults (32-34). While present eye tracking studies provide insights into the social attention in autism, a paucity of research have directly utilised eye tracking measures in conjuction with an explicit social emotional measure.

In light of previous research, the present thesis sought to leverage eye-tracking methods for assessing the altered social emotional processing of autistic individuals. The following two chapters of this thesis present two experimental tasks aiming to gain a better understanding of social emotional processing in autistic adults. Both tasks combined measures of social emotional performance with eye-tracking assessment, allowing for concurrent examination of strategies autistic adults employ during processing of social emotional information and their ability to accurately comprehend such information. More specifically, Chapter 5 and 6 firstly aimed to determine whether altered gaze patterns may underlie the social emotional processing difficulties in autism. The eye tracking results informed the usefulness of targeting eye gaze patterns for a social emotional intervention for autistic adults. Secondly, the following two chapters investigated two different ecologically valid assessments, informing the selection of suitable distant generalisation measures for evaluating social emotional interventions for autistic adults.

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# Chapter 5 : Emotion recognition performance of autistic and non-autistic adults on the Reading the Mind in Films Test

This chapter presents a manuscript that has been published in Journal of Autism and Developmental Disorders, **impact factor 2.786**:

**Tang, J. S. Y.**, Chen, N. T. M., Falkmer, M., Bölte, S., & Girdler, S. (2019). Atypical visual processing but comparable levels of emotion recognition in adults with autism during the processing of social scenes. *Journal of Autism and Developmental* Disorders, *49*(10), 4009–4018. https://doi.org/10.1007/s10803-019-04104-y

# Author contribution statement: Chapter 5

As co-authors of the paper entitled, ‘Atypical visual processing but comparable levels of emotion recognition in adults with autism during the processing of social scenes’, we confirm that Julia Tang has been the principal research and has made the following contributions:

- Conceptualisation and design of the research;
- Data collection (joint effort between two PhD candidates)f, analysis and interpretation;
- Writing the manuscript and critical appraisal of the findings; and
- Corresponding author for communication with the journal.

Our contribution to the paper was consistent with the role of supervisors and involved the following contributions:

- Assistance with conceptualisation and design of the research;
- Assistance with analysis and interpretation; and
- Review and editing of the manuscript

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|---|---|---|
| Signed: | Nigel TM Chen | Date: 28.05.2020 |
| Signed: | Marita Falkmer | Date: 28.05.2020 |
| Signed: | Sven Bölte | Date: 28.05.2020 |
| Signed: | Sonya Girdler | Date: 28.05.2020 |

# Preface

Ecologically valid assessments incorporate audiovisual vignettes closely representing the dynamic complexities of real life social environments. These assessments regarded as sensitive to predicting real world social functioning, hence proposed as potentially suitable as a distant generalisation outcome measure for evaluating social emotional interventions targeting autistic adults. Chapter 5 of this thesis examined the potential of the Reading the Mind in Films test as a distant generalisation outcome measure for evaluating social emotional interventions for autistic adults. The study further investigated the visual search strategies of autistic adults while processing the social emotional scenes in the Reading the Mind in Films test.

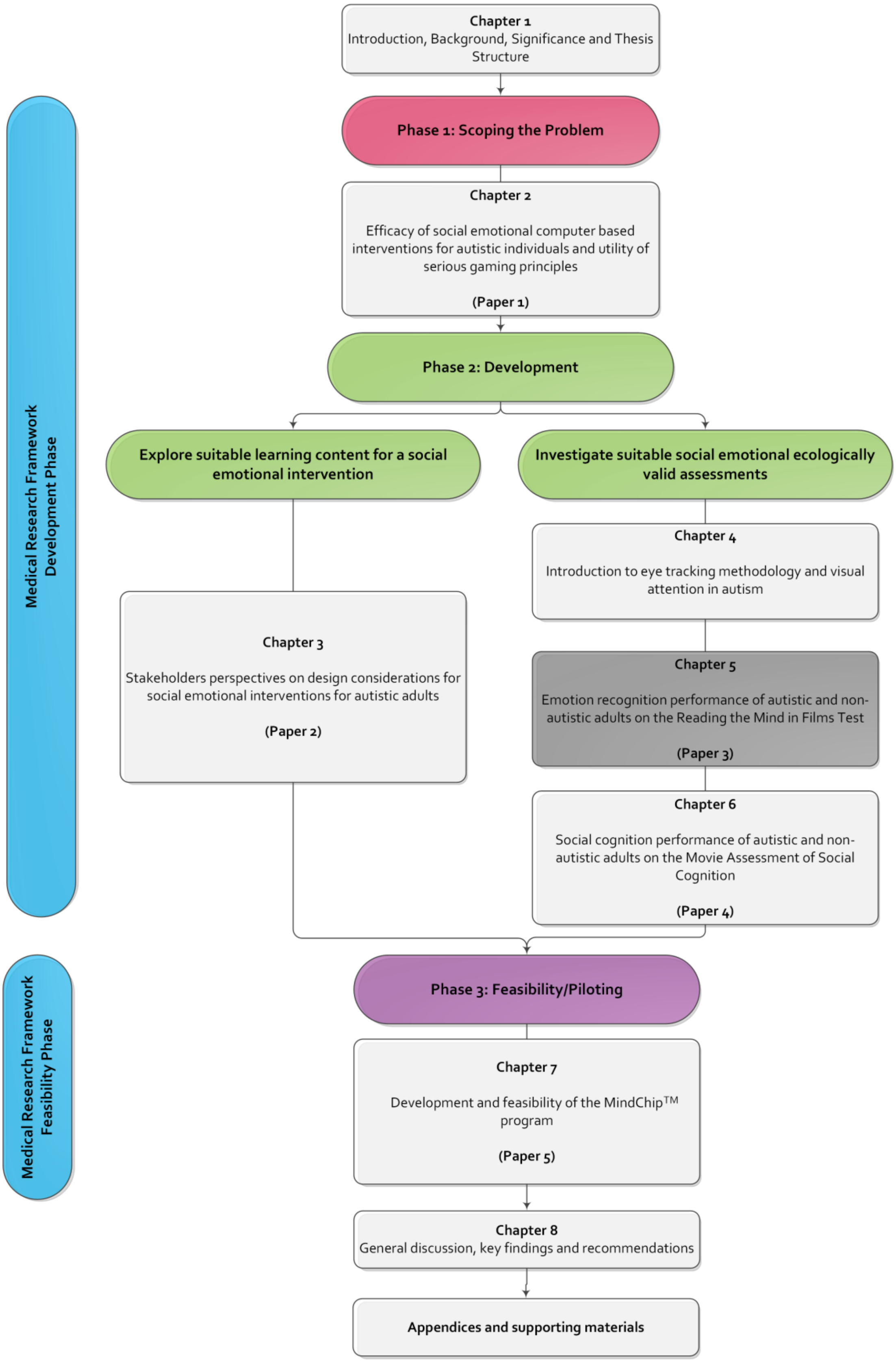


**Figure 5.1. Thesis structure Chapter 5.**

Journal of Autism and Developmental Disorders
https://doi.org/10.1007/s10803-019-04104-y

ORIGINAL PAPER

# Atypical Visual Processing but Comparable Levels of Emotion Recognition in Adults with Autism During the Processing of Social Scenes

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**Abstract**
Understanding the underlying visual scanning patterns of individuals with autism spectrum disorder (ASD) during the processing of complex emotional scenes remains limited. This study compared the complex emotion recognition performance of adults with ASD ($n = 23$) and matched neurotypical participants ($n = 25$) using the Reading the Mind in Films Task. Behaviourally, both groups exhibited similar emotion recognition accuracy. Visual fixation time towards key social regions of each stimuli was examined via eye tracking. Individuals with ASD demonstrated significantly longer fixation time towards the non-social areas. No group differences were evident for the facial and body regions of all characters in the social scenes. The findings provide evidence of the heterogeneity associated with complex emotion processing in individuals with ASD.

**Keywords** Autism · Dynamic stimuli · Eye tracking · Naturalistic · Social cognition

Social communication is a multifaceted process, underpinned by fundamental skills including the interpretation of the emotional states and thoughts of others (Adolphs 2001; Frith and Blakemore 2006). Recognition of expressed emotions involves integrating nonverbal and verbal cues, including facial expressions, body gestures, contextual cues and vocal prosody (Borod et al. 2000). The developmental course of emotion processing typically begins in early infancy with individuals continuing to develop their emotion recognition repertoire with age (Durand et al. 2007). Infants between 4–7 months have the emerging ability to recognise happy and sad (Walker-Andrews 1998; Young-Browne et al. 1977). By the age of 10, children have mostly achieved adult level proficiency in emotion recognition ability (Mondloch et al. 2003). As individuals progress into adolescence and adulthood, they gradually develop efficiency in processing increasingly complex emotions.

Atypical emotion recognition processing is postulated to underpin the social communication difficulties observed in autism spectrum disorders (ASD) (Baron-Cohen 2004; Williams and Gray 2013). Behavioural studies investigating the emotion processing abilities of individuals with ASD across the developmental trajectory, report a lack of progressive increase in maturation of emotion recognition abilities among individuals with ASD compared to neurotypical individuals (Lozier et al. 2014). While reduced emotion recognition accuracy has been reported from basic (Bölte and Poustka 2003; Eack et al. 2015; Falkmer et al. 2011; Griffiths et al. 2017; Uljarevic and Hamilton 2013) to complex emotions among individuals with ASD with normal intellectual functioning (Fridenson-Hayo et al. 2016; Golan et al. 2006a), some studies report comparable emotion

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Published online: 15 June 2019

recognition performance to neurotypical controls (Castelli 2005; Leung et al. 2013). The heterogeneity in the current literature limits our ability to delineate the precise developmental course of emotion processing in ASD. Discrepancies in these findings are likely due to variations in experimental demands and demographic factors (Harms et al. 2010). For instance, studies assessing the recognition of basic emotions often yield mixed findings, with some reporting comparable recognition in individuals with ASD (McCabe et al. 2013; Spezio et al. 2007) and others observing decreased basic emotion recognition accuracy for individuals with ASD (Berggren et al. 2016; Falkmer et al. 2011). Other studies suggested emotional valence influences emotion recognition performance in ASD with differing accuracy in negatively valanced emotions, but not positive basic emotions (Ashwin et al. 2006). There is evidence of a selective impairment in emotions with briefer presentation duration, suggesting a delayed spontaneous processing of emotional expressions for individuals with ASD (Clark et al. 2008).

Variation in stimulus presentation may offer another explanation of the heterogeneous findings reported in the current literature (Harms et al. 2010; Nuske et al. 2013). Contemporary emotion recognition experimental designs in ASD have largely focused on presenting static and typical basic emotions, with few studies employing dynamic stimuli with naturalistic elements. Static prototypical stimuli may not accurately reflect the demands of everyday social interactions, which often require rapid processing of multiple social cues. This would be in line with previous research comparing the performance of people with ASD and neurotypical controls on both static and dynamic emotional stimuli, concluding that emotion recognition accuracy during viewing of dynamic stimuli has more consistently differentiated these groups (Cassidy et al. 2015; Chevallier et al. 2015). Neuroimaging studies have reported differential neuro activation amongst individuals with ASD when presented with dynamic relative to static expressions, with the former reporting reduced activation in social brain regions such as the amygdala and fusiform gyrus (Pelphrey et al. 2007). A more nuanced understanding of the multimodal emotion processing abilities of individuals with ASD may depend on additional research employing more ecologically valid stimuli.

To date, previous ASD related research adopting dynamic naturalistic stimuli has predominantly focussed on evaluating impairments in mentalising or theory of mind (Mathersul et al. 2013; Müller et al. 2016; Murray et al. 2017; Rosenblau et al. 2015) with comparably fewer studies utilising dynamic naturalistic stimuli specifically in the context of emotion recognition. One such assessment is the Reading the Mind in Films Task (RMFT). This task examines the ability to identify complex emotional concepts from video clips of social scenes. Previous work using the RMFT has observed impaired emotion recognition accuracy in children and adults with high functioning ASD compared to neurotypical controls (Golan et al. 2006b, 2008). While this research suggests that ASD may be associated with difficulties in the ability to extract complex emotional information from social scenes, further exploration of the underlying mechanisms contributing to this impairment is warranted (Bird et al. 2011; Klin et al. 2002; Nakano et al. 2010).

Eye tracking may provide valuable insights into the visual processing mechanisms underpinning the emotion recognition performance of individuals with ASD. Systematic reviews in this area report collective evidence for divergent gaze patterns towards facially expressed emotions and eye avoidance amongst adults with ASD (Black et al. 2017; Harms et al. 2010). However, findings from eye tracking studies in ASD are somewhat inconsistent, a pattern linked to factors such as heterogeneity in study design and participant demographics (Guillon et al. 2014). While some research report that adolescents and adults with ASD have reduced eye gaze towards dynamic faces and social stimuli compared to neurotypical controls (Bird et al. 2011; Klin et al. 2002), others report similar visual scanning patterns when comparing participants with and without ASD (Kuhn et al. 2010; Nakano et al. 2010). The role of atypical gaze strategies in contributing to ASD-linked difficulties in recognising complex emotional information from naturalistic social contexts needs to be further understood.

The present study therefore sought to examine the visual processing mechanisms of adults with ASD during the recognition of complex emotional concepts presented within naturalistic social scenes. In light of previous research (Golan et al. 2006b), we administered the RMFT to adults with ASD and neurotypical controls. Eye gaze was recorded throughout this assessment, enabling comparison of the visual processing mechanisms of both groups. Specifically, it was hypothesised that

(1) Adults with ASD compared to neurotypical adults would be less accurate in recognising the complex emotional concepts presented in social scenes.
(2) Adults with ASD compared to neurotypical adults would exhibit reduced percentage of fixation time towards target characters (i.e. the subject of the emotional information) and greater fixation time towards non-social display regions for each social scene.

## Methods

### Participants

Adults with ASD and neurotypical adults were recruited via the Curtin University Autism Research Group community pool and local service providers throughout Perth, Western

Australia. Participants with ASD had a confirmed diagnosis of ASD based on consensus from a multidisciplinary team, Asperger's syndrome (AS), or Pervasive developmental disorder—Otherwise not specified (PDD-NOS) as specified under the Diagnostic and Statistical Manual of Mental Disorders-5 (DSM-5) (American Psychiatric Association 2013) or according to the previous DSM-IV diagnostic criteria (American Psychiatric Association 2000). At present, diagnostic processes involving assessments within multidisciplinary team is considered the 'goal standard' for autism diagnosis in Australia (Whitehouse et al. 2018). Participants with ASD diagnosed with significant neurodevelopmental and/or mental health disabilities, such as intellectual disability, epilepsy and bipolar disorder were excluded. Neurotypical adults with no history of neurodevelopmental disorder or current psychiatric diagnoses, scoring below the clinical cut-off (raw score of 68) for autistic traits measured using the adult self-report Social Responsiveness Scale (SRS-2) (Constantino and Gruber 2011) were eligible for inclusion. All participants were required to have sufficient understanding of verbal and written English language, and normal or corrected vision. In total, 69 individuals were initially recruited for this study. Twelve adults with ASD were subsequently excluded, due to the absence of a confirmed ASD diagnosis (n = 2), significant comorbidities (intellectual disability, n = 2; bipolar disorder, n = 1), technical issues during data recording (n = 5), or eye tracking calibration failure (n = 2). Nine neurotypical adults were excluded for scoring above the SRS-2 cut-off for clinically significant symptoms (n = 5) and technical issues in data recording (n = 4). Neurotypical adults were matched with the participants with ASD according to age, gender, Verbal Comprehension Index (VCI), Perceptual Reasoning Index (PRI) and Full Scale Intelligence Quotient (FS-IQ) (Wechsler 2011). The final sample included 23 adults with ASD (age $M = 25.81$, $SD = 9.91$ years) and 25 matched neurotypical adults (age $M = 27.31$, $SD = 9.00$ years). Table 1 summarises the participants' demographic characteristics. This study was approved by the Human Research Ethics Committee at Curtin University, Perth, Western Australia (Approval Number: 52/2012).

## Measures

### Social Responsiveness Scale—Second Edition

The Social Responsiveness Scale—Second edition (SRS-2) Adult Self Report (Constantino and Gruber 2011) screens for autistic trait severity, consisting of 65 four-point Likert scaled items relating to five dimensions; social awareness, social cognition, social communication, social motivation and restricted interests and repetitive behaviours. Total raw scores above 67 indicate mild to severe autism symptomology. The SRS-2 has demonstrated excellent internal consistency ($r_{tt} = .94–.96$), good test–retest reliability ($r_{tt} = .88–.95$) and reliability coefficients ($r_{tt} = .61–.92$) (Bruni 2014), and is validated cross culturally (Bölte, Poustka and Constantino 2008).

### Wechsler Abbreviated Scale of Intelligence—Second Edition

The Wechsler Abbreviated Scale of Intelligence—Second edition (WASI-2) (Wechsler 2011) is the abbreviated version of the Wechsler Adult Intelligence Scale—Fourth edition, assessing general cognitive abilities across verbal reasoning (vocabulary and similarities) and perceptual reasoning (Block Design and Matrix Reasoning). The WASI-2 has shown excellent internal consistency ($r_{tt} = .90–.92$), stability coefficients ($r_{tt} = .83–.94$) and inter-rater reliability ($r_{ir} = .94–.99$) (McCrimmon and Smith 2012).

### Reading the Mind in Films Task

The Reading the Mind in Films-Adult Task (RMFT) provides an ecologically valid assessment of complex emotion recognition skills (Golan et al. 2006b), comprising of 22 social scenes taken from four movies. Each scene conveys an emotional state of a specified character within varying social contexts. For example, social scenes range in number of characters (one to five main characters) and settings (home and public settings). Prior to watching each scene, a

**Table 1** Participants characteristics

| | ASD adults (n = 23) | | Neurotypical adults (n = 25) | | |
|---|---|---|---|---|---|
| | Mean (SD) | Range | Mean (SD) | Range | *p*-value |
| Age (years) | 25.27 (8.86) | 18.15–50.75 | 27.31 (9.00) | 19.36–54.75 | .33 |
| Gender (male/female) | 18/5 | – | 19/6 | – | .50 |
| SRS raw score | 79.25 (26.50) | 48.00–136.00 | 38.17 (16.53) | 15.00–65.00 | <.01* |
| Verbal IQ | 101.45 (12.54) | 73.00–119.00 | 102.96 (11.72) | 85.00–121.00 | .55 |
| Performance IQ | 106.55 (18.89) | 61.00–137.00 | 107.71 (14.07) | 76.00–135.00 | .64 |
| Full scale IQ | 104.30 (13.50) | 72.00–130.00 | 106.00 (11.68) | 79.00–130.00 | .47 |

*indicates significant results

target character is specified with participants requested to identify the character's expressed emotion at the end of the scene. All film clips include the dialogue associated with the original movie clip. After watching each film clip, a question slide with four multiple choice options appeared and participants were requested to indicate which emotion best represents the emotion of the target character at the end of the scene by pressing a key on a keyboard.

### Apparatus

Eye tracking data was recorded using the SensoMotoric Instruments 60 Hz remote eye tracker (RED), a stationary contact-free device, capturing movements within a 40×20 cm range at a distance of 70 cm. The RED recording unit was integrated with two external devices, a laptop controlling data acquisition and a 40 inch television screen for stimuli presentation. The experimental setup was managed via SMI Experiment Centre and presented in 800×600 pixels. IViewX in 60 Hz managed the eye movement data acquisition.

### Procedure

Following completion of socio-demographic questionnaires and screening assessments, participants were oriented to the eye tracker and completed a five-point calibration protocol. Since the RMFT was sampled from four featured movies and series, participants firstly indicated whether they had previously watched any of these films. All participants confirmed that they were naïve to all four movies. Verbal instructions were then provided followed by one practice trial. The question slide orienting the participants to a target character and four multiple choice options was shown prior to each video clip. This was followed by a one second fixation cross and the video clip. After presenting the video clip, the question slide was presented for a second time and participants were asked to indicate their answer on the keyboard before moving on to the next question. The presentation order for each task is shown in Fig. 1. No restriction was placed on response time. All participants were provided with a handout with a list of definitions of each emotion.

### Data Preparation

Behavioural and eye tracking data output was obtained from SMI BeGaze software and managed using SPSS Version 24. Trials were excluded from analysis if the eye tracker failed to detect any gaze throughout the trial. Percentage accuracy scores were calculated by summing the total number of correct responses divided by the number of included trials. Gaze measures were derived from correct response trials only, in order to conduct a direct observation of instances when the emotion recognition occurred.

Participants with calibration data exceeding 1.5° visual angle were excluded from the analysis. Fixations were defined as gaze samples held within 1° visual angle for a minimum duration of 100 ms (Falkmer et al. 2008). Rectangular areas of interests were then dynamically defined over the facial and body regions of the 'target character' (central character identified in the video) and 'other characters' (supporting characters in the video scene). An example of the defined areas of interests is shown in Fig. 2. A fifth interest area 'elsewhere' was defined as the remaining areas of the display not occupied by the other interest areas. For each video, the total fixation time to each interest area was then calculated as a percentage relative to the video duration. From this, the average percentage of fixation time was then derived for the 'target character face', 'target character body' 'other character face' 'other character body' and 'elsewhere' areas of interest.

### Statistical Analysis

Group characteristics between ASD and neurotypical adults were compared using an independent $t$ test for continuous data. To determine if the distribution of gender between groups matched, gender comparison was analysed using Chi

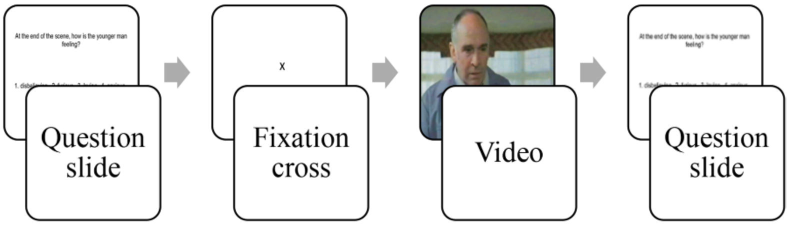


**Fig. 1** Order of presentation for each question in Reading in the Mind in Films task. (1) Question slide, (2) fixation cross to validate the eye tracking recording, (3) video, (4) question slide was presented the second time and participants recorded their answers (Golan et al. 2006a; 2006b, p. 116)

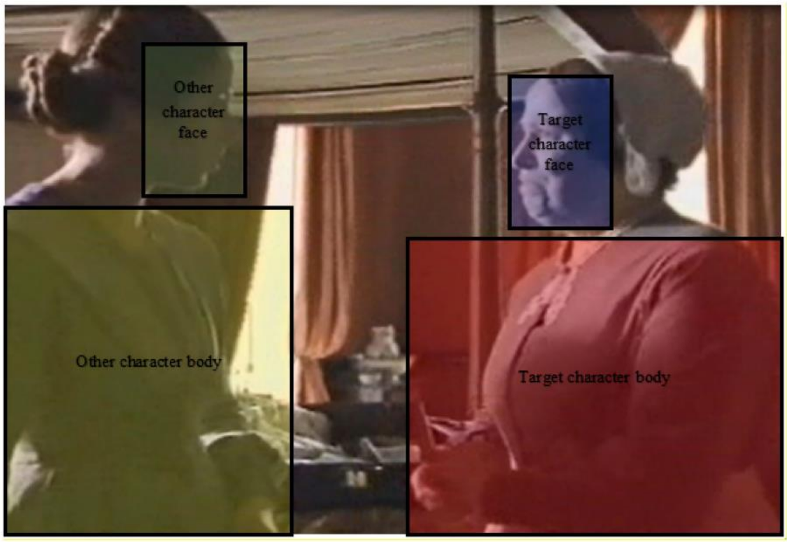


**Fig. 2** Example of defined area of interests, 'target character face', 'target character body', 'other character face', 'other character body'. Areas outside of the defined area of interests were specified as 'elsewhere' (Golan et al. 2006a; 2006b, p. 116)

square test. Greenhouse–Geisser correction was applied for analyses violating the assumption of sphericity. Partial eta squared, $\eta^2$ was reported for effect size calculations, with alpha value, α applied at p = 0.05.

## Results

### Emotion Recognition Accuracy

Emotion recognition accuracy was analysed using one-way analysis of variance (ANOVA) to determine group differences between participants with and without ASD. No significant group differences in emotion recognition accuracy, were found $F(1,45.06) = 0.22$, $p = 0.64$, partial $\eta^2 = 0.01$. Participants with ASD had a similar performance to the neurotypical participants in recognising complex emotions (ASD, $M = 55.50\%$, $SD = 15.10$; TD, $M = 57.45\%$, $SD = 13.82$).

### Percentage Fixation Time

To examine the group differences in fixation time, a group (ASD vs. neurotypicals) by 5 area of interests (target character face vs. other character face vs. target character body vs. other character body vs. elsewhere) factorial repeated measures ANOVA was conducted. As Mauchly's Test of Sphericity indicated a violation of the assumption of sphericity, $\chi^2(9) = 152.75$, $p < 0.01$, Greenhouse–Geisser correction was applied. Analysis revealed a main effect of area of interest, $F(1.6, 28979.38) = 146.93$, $p < 0.01$, partial $\eta^2 = 0.76$, which importantly was qualified by a significant group by area of interest interaction, $F(1.6, 732.09) = 3.71$, $p = 0.04$, partial $\eta^2 = 0.08$.

Follow up pairwise comparisons with Bonferroni adjustments indicated that participants with ASD ($M = 20.24\%$, $SD = 14.73$) compared to neurotypical participants ($M = 13.38\%$, $SD = 6.21$) had an increased fixation time towards 'elsewhere', $p = 0.04$ (Fig. 3). There was a near significant trend, indicating participants with ASD ($M = 39.14\%$, $SD = 11.65$) had reduced fixation time towards 'target character face' compared to neurotypical adults ($M = 45.68\%$, $SD = 11.50$), $p = 0.06$. No other group differences in fixation time was found.

## Discussion

The current study investigated the gaze strategies of adults with ASD and neurotypical controls during the processing of complex emotional content in naturalistic social scenes. The findings revealed an interesting contrast between the emotion recognition performance and the visual processing mechanisms employed by each group. While participants with ASD demonstrated comparable emotion recognition performance to controls, there was evidence of divergent gaze patterns towards non-social information. These findings offer insights into the possible visual processing strategies adopted by individuals with ASD during the processing of social information and recognition of complex emotional social scenes.

This study predicted that adults with ASD would be less accurate in recognising complex emotions presented in a dynamic ecologically valid assessment, a hypothesis consistent with previous research (Golan et al. 2006b, 2008; Müller et al. 2016). This prediction was however not supported, with comparable performance observed across adults with ASD and their neurotypical peers in emotion recognition accuracy. These findings suggest that adults with ASD with normal to above intelligence quotients have an intact ability to recognise emotions during the viewing of social scenes (Gepner et al. 2001; Hillier and Allinson 2002; Tracy et al. 2011), and that emotion recognition difficulties may not be universally present in ASD (Nuske et al. 2013).

It is possible that certain methodological factors may have contributed to the discrepancies in emotion recognition accuracy findings between the current study and those of Golan et al. (2006b). Previous research indicates that the emotion recognition difficulties of individuals with ASD becomes increasingly apparent during tasks with increasing complexity (Harms et al. 2010; Nuske et al. 2013). The presence of complex emotions presented in an ecologically valid manner suggest that the RMFT should be sufficiently complex for adults with ASD. The RMFT contains four multiple choice options, reducing the probability of individuals performing above chance levels, as evident in this study. In addition, no ceiling effect was observed for either group. Despite the advantages of the RMFT, an absence of difference in emotion recognition accuracy suggest that the RMFT may not be sufficiently complex to illicit differences in emotion recognition

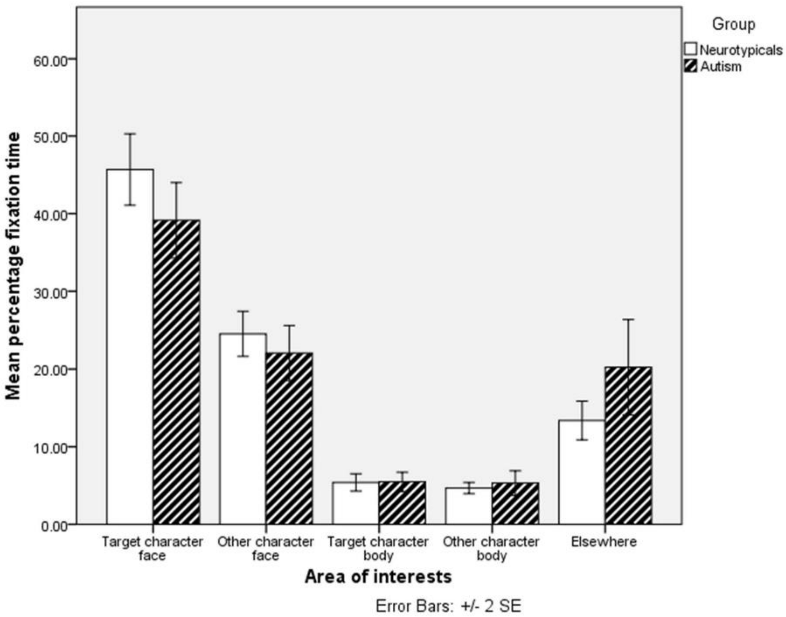


**Fig. 3** Average proportion fixation time across all area of interest, target character face, target character body, other character face, other character body and elsewhere in adults with ASD and neurotypicals

performance between individuals with ASD and neurotypical individuals. A previous review reported emotion recognition deficits in ASD typically appear during tasks with increasing attentional and cognitive demands, including tasks providing explicit prompting of the presented emotion (Nuske et al. 2013). Guided by the previous experimental protocol of the RMFT, this task is explicit in its presentation of social scenarios, with scenarios bookended by questions such as, "At the end of the scene, how is the younger man feeling?" presented before and after the social scenario. These questions explicitly direct participants towards the central character within a scenario and may serve to alleviate some of the cognitive demand associated with emotion processing (Klin 2000), possibly enabling the participants with ASD to correctly recognise the emotion. Pre-prompting was previously reported to improve the emotion recognition performance and alter the visual search patterns in ASD, reducing the deviance observed between individuals with ASD and neurotypical individuals (Joosten et al. 2016; Kliemann et al. 2013; Senju 2013). Additionally, the RMFT presented response items in a multiple choice format, allowing an unrestricted time to respond, possibly alleviating some of the cognitive demand associated with the processing requirements of these tasks (Clark et al. 2008; Klin 2000; Nuske et al. 2013; Tardif et al. 2007). Further insights may be gained from designs which impose time constraints on response time and present varying, and even open ended response formats.

The eye tracking measurements obtained in this study revealed that in comparison to controls, the individuals with ASD spent a greater percentage of time fixating on the non-social regions of the scenes, which were perhaps more peripheral in conveying emotional tone. No other significant results in eye gaze was found, although one trend was observed suggesting that individuals with ASD may have spent less time processing the target characters, who were the subject of the emotional content of each scene. These findings are consistent with research reporting that individuals with ASD direct less of their visual attention towards socially salient stimuli (Chita-Tegmark 2016; Guillon et al. 2014) and may not prioritise social information as neurotypical individuals (Sato et al. 2017).

Interestingly, the evident atypical visual processing of social stimuli was observed in conjunction with comparable behavioural performance. This combination of results suggests that the individuals with ASD may have potentially employed altered processing strategies during emotion recognition (Harms et al. 2010). Given that comparable visual attention was found for body and increased fixation time towards 'elsewhere', it is possible that the participants with ASD were utilising other visual modalities such as body language or contextual cues to successfully infer the emotional state of the target character. Consistent with this notion, previous studies have reported that individuals with ASD may show comparable recognition of body language, but reduced recognition of facially expressed emotion, suggesting varying emotion recognition abilities in individuals with ASD across different modalities (Nuske et al. 2013; Peterson et al. 2015). Future research might experimentally manipulate these regions, such as through occlusion, examining the differential impact this has on the performance of individuals with ASD, compared to controls. Findings from this study highlight the need to further explore the potential role of altered processing style employed by individuals with ASD during the processing of naturalistic social emotional information. Future research may seek to further explore why atypical gaze patterns present in the absence of a concurrent emotion recognition difficulties.

Dynamic ecologically valid assessments such as the RMFT presents social information with visual and auditory information, permitting the evaluation of multisensory integration abilities of participants with ASD in understanding emotion cues (Magnée et al. 2011). While adults with ASD demonstrated intact emotion recognition behavioural performance, differences in eye tracking results observed between adults with ASD and neurotypical adults suggests altered audio-visual processing strategy in ASD. It is plausible that individuals with ASD may draw on auditory information when interpreting complex social emotional scenarios (Rice et al. 2012). However, since unimodal visual versus auditory processing was not investigated, conclusive evidence on individual with ASD's ability in audio-visual processing could not to be determined in this study. Research examining the effect of separating the visual and auditory information presented in the RMFT on the performance of individuals with ASD relative to neurotypical controls may provide further insights in audio-visual processing and emotion recognition abilities in individuals with ASD.

## Limitations

The RMFT employed in the current study, presented videos of social scenarios with visual and auditory information varying in nuanced emotional tone. The ecological validity of this task represents a strength of the present work in enabling unique insights into how complex emotional content may be extracted from naturalistic social situations, providing understanding towards the nature of emotion processing for adults with ASD. However, limitations of the present study are also acknowledged, including the nature of the clinical sample used. For the present study, all participants with ASD may be considered higher-functioning as they all exhibited normative levels of verbal and intellectual ability. It is possible that this may have contributed to the higher levels of emotion recognition accuracy observed for this group

(Harms et al. 2010). Caution in the generalisation of the present findings is therefore warranted, given the nature of the clinical sample used. While the present findings suggest that ASD is associated with altered attentional processing of social emotional scenes, it is noted that only a modest sample size was collected for the present study. Future research may seek to determine whether the present findings may be replicated across larger samples.

## Conclusion

In summary, the present study provided evidence that the recognition of complex emotional concepts may be intact for adults with ASD, in response to the viewing of naturalistic social scenarios. Concurrent findings of aberrant gaze behaviour for these individuals however, points towards an altered processing style compared to neurotypical perceptions of social salience. This study provides understanding of the emotion recognition mechanisms which may characterise ASD.

**Acknowledgments** The researchers would like to extend our gratitude to the participants for the time and effort taken to participate in this study as well as Melissa Black, who assisted in data collection.

**Author Contributions** JT conceptualised and designed the study, involved in data collection, analysed and interpreted the data, and contributed to drafting the article. NC conceptualised and designed the study, analysed and interpreted the data and critically revised the draft. MF conceptualised and designed the study, interpreted the data, and revised the draft. SB revised and critically contributed to the intellectual content of the article. SG conceptualised and designed the study, interpreted the data and critically revised the article. All authors contributed to and have approved the final manuscript.

**Funding** This research is supported by the Cooperative Research Centre for Living with Autism (Autism CRC) [Project Number 3.032RS], established and supported under the Australian Government's Cooperative Research Centres Program. JT is supported through an Australian Government Research Training Program Scholarship.

## Compliance with Ethical Standards

**Conflict of interest** The authors declare that they have no conflict of interest. SB reports no direct conflict of interest related to this article. SB discloses that he has in the last 5 years acted as an author, consultant or lecturer for Shire, Medice, Roche, Eli Lilly, Prima Psychiatry, GLGroup, System Analytic, Kompetento, Expo Medica, and Prophase. He receives royalties for text books and diagnostic tools from Huber/Hogrefe, Kohlhammer and UTB.

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# Chapter 6 : Social cognition performance of autistic and non-autistic adults on the Movie for the Assessment of Social Cognition

This chapter presents a manuscript that has been submitted.

**Tang, J. S. Y.,** Chen, N. T. M., Falkmer, M., Bölte, S., Black, M. H. & Girdler, S. (2020). *Naturalistic social cognition and visual scanning in autistic adults*. Manuscript submitted for publication.

# Author contribution statement: Chapter 6

As co-authors of the paper entitled, '*Naturalistic social cognition and visual scanning in autistic adults*', we confirm that Julia Tang has been the principal research and has made the following contributions:

- Conceptualisation and design of the research;
- Data collection, analysis and interpretation;
- Writing the manuscript and critical appraisal of the findings; and
- Corresponding author for communication with the journal.

Our contribution to the paper was consistent with the role of supervisors and involved the following contributions:

- Assistance with conceptualisation and design of the research;
- Assistance with analysis and interpretation; and
- Review and editing of the manuscript

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| Signed: | Nigel TM Chen | Date: 28.05.2020 |
| Signed: | Marita Falkmer | Date: 28.05.2020 |
| Signed: | Sven Bölte | Date: 28.05.2020 |
| Signed: | Sonya Girdler | Date: 28.05.2020 |

My contribution to the paper was consistent with the role of a co-author and involved the following contributions:

- Conceptualisation and design of the research; and
- Review and editing of the manuscript

| | | |
|---|---|---|
| Signed: | Melissa Black | Date: 29.05.2020 |

# Preface

Findings from Chapter 5 concluded no significant differences in RMFT accuracy performance between autistic and non-autistic adults. The results indicate that this assessment may not be a suitable ecologically valid assessment for detecting social emotional changes in response to an intervention. Given the findings from Chapter 5, Chapter 6 investigated another ecologically valid assessment, the MASC as a potential distant generalisation measure for this thesis. Chapter 6 aimed to compare the social emotional performance and visual search strategies of autistic and non-autistic adults on the MASC.

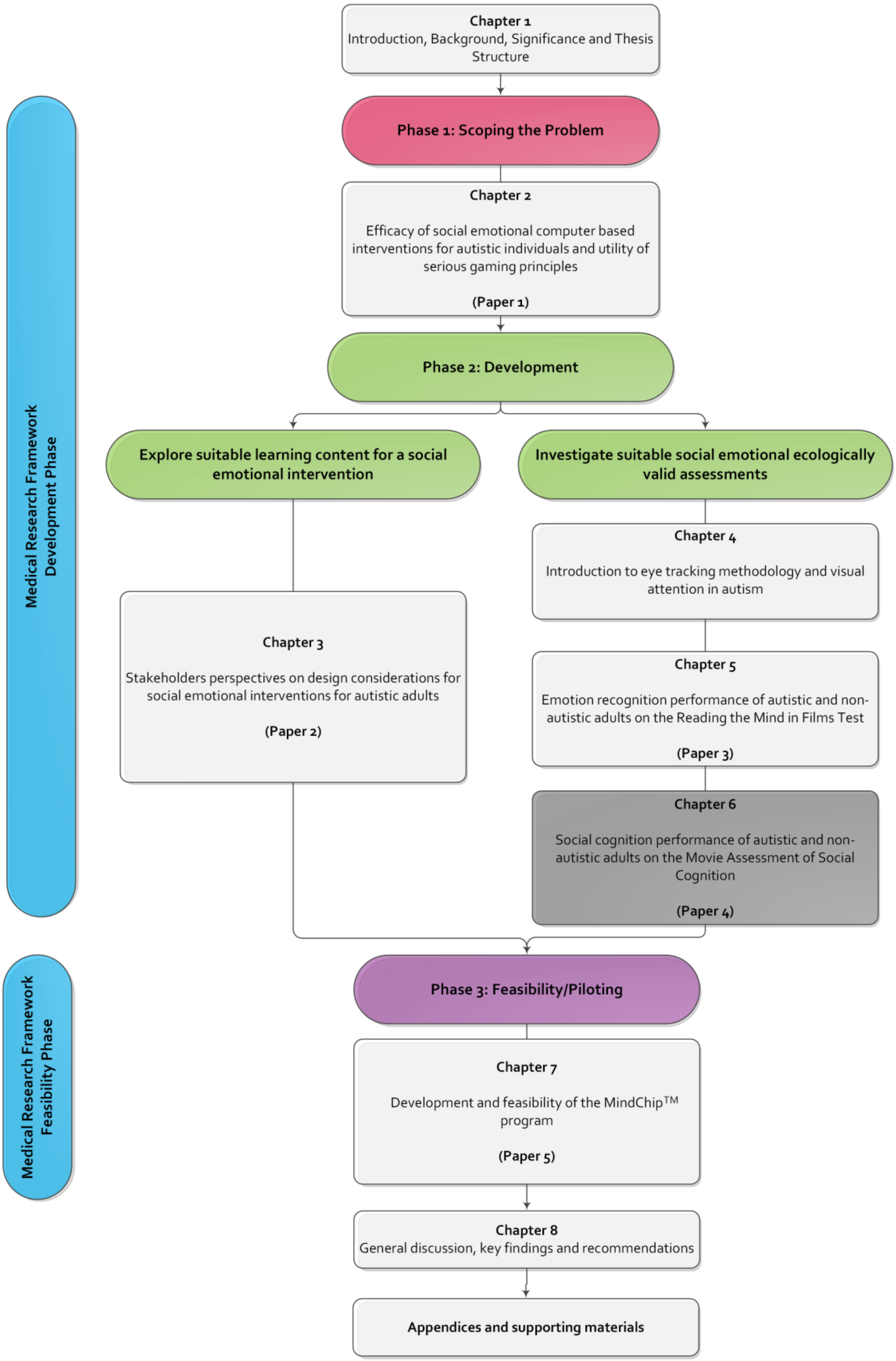


**Figure 6.1. Thesis structure Chapter 6.**

# Naturalistic social cognition performance and visual scanning in autistic adults

## Abstract

The Movie for the Assessment of Social Cognition (MASC) utilises dynamic naturalistic stimuli for evaluating broader social cognition performance. In this study, the English multiple choice version of the MASC was administered with eye tracking, investigating the social cognition skills of 25 autistic adults and 25 non-autistic adults matched for age and intellectual functioning. Autistic adults demonstrated more social cognition difficulties, fewer head fixations and more fixations towards non-social aspects of the MASC compared to the non-autistic group. Fixations to core facial regions, including the eyes, nose and mouth did not differ between groups. ROC analysis revealed that the MASC was more sensitive social cognition measure compared to a dynamic emotion recognition assessment. Intellectual functioning was positively associated with MASC performance in the autistic group. Fixation time did not correlate with MASC performance. Findings support previous reports of underlying social cognition difficulties in autistic individuals. However, these difficulties were not consistently related to the previously postulated visual scanning patterns of faces, highlighting the importance of considering the heterogeneity of autism in understanding the variability in social cognitive performance of autistic adults.

*Keywords:* Autism Spectrum Disorder, fixation duration, mentalising, theory of mind

# Introduction

Social cognition processes are influenced by social awareness and motivation and describe the processes for acquiring social emotional information to inform relevant social behavioural responses (1). It is proposed as a multidimensional construct, often distinguished by affective and cognitive processes (2), with affective social cognition delineating recognising and interpreting verbal and nonverbal emotional cues, and cognitive components describing understanding the beliefs of others (3, 4). Successful social cognition interpretation requires both implicit and explicit processing of social information (5). Implicit social cognition describes spontaneous and automatic processes, while explicit social cognition encompasses conscious and controlled processing (6, 7). Executive functioning skills relating to language processing, memory of previous experiences and response inhibition are important components for integrating both implicit and explicit social cognition processes (6, 8).

Developmentally, evidence suggests that 18 month old non-autistic toddlers demonstrate the initial precursors to social cognition skills, including understanding joint attention, pretence and some emotional intentions (9). By three to five years of age, children can intuitively make associations between a physical object and a person's thoughts, understanding that an individual's belief may contradict reality (9-11). While autistic individuals reportedly follow a consistent sequential increase in social cognitive abilities, their developmental progression appears to follow a different pathway (12) or is delayed compared to non-autistic social cognition development (13-15). A recent meta-analytic review found autistic individuals demonstrated difficulties across a range of social cognition paradigms, with larger difficulties evident in response to more complex social cognition task demands ($d$ = -0.94) (16). Despite these findings, evidence remains inconclusive, with some studies reporting comparable social cognition performance with non-autistic individuals in a subset of autistic individuals, suggesting a heterogeneity of social cognition skills among autistic individuals (17, 18). Heterogeneity in social cognition skills are likely due to the nuances in language, explicit and implicit demands of social cognition tasks, and variation in executive functioning and social skills (19-22).

Until relatively recently, measurement frameworks evaluating social cognition in autism have largely been operationalised using static stimuli or written formats, often lacking sufficient reliability due to observed ceiling effects (23, 24). For example, Happé's Advanced Strange Stories Task contains 24 vignettes, each with two accompanying questions, evaluating social reasoning and justification (18). Another example, the 'fortune of others' task includes an assessment utilising cartoon pictures for evaluating first and second order theory of mind (25). It may, however, be argued that static assessments are insufficient in capturing the complexity and dynamic nature of social interactions (26). Previous studies have reported divergent processing styles in autism in response to static and more ecologically valid stimuli, including variation in visual search strategies (27) and neural processing patterns (28), emphasising the need to employ more ecologically valid measurements in understanding social cognitive skills in autism.

More recently assessments have begun to draw on audiovisual vignettes which present more naturalistic representations of everyday situations (26, 29). The Movie for the Assessment of Social Cognition (MASC) is an example of an ecologically valid measurement of social cognition skills in autism, involving video narratives between four friends interacting together during joint activities (30). The development of MASC is underpinned by theoretical constructs, assessing both affective and cognitive components of social cognition, using multiple choice questioning on emotions, thoughts and intentions. Previous psychometric evaluations indicate that the MASC has strong psychometric constructs, including good internal consistency ($\alpha = 0.84$) and test-retest reliability (ICC = 0.97), drawing on a sample ($N = 56$) of reported autistic adolescents and adults in Germany (30, 31). Validation studies with French and Spanish samples yielded group differences between autistic and non-autistic individuals (13, 32). An English dubbed version of the MASC was evaluated in a study in United Kingdom, demonstrating good sensitivity and a large effect size for measuring social cognitive skills between autistic and non-autistic adults ($d = 1.1$) (33). Validation studies utilising dubbed material reported differing results from the original MASC validation (30, 32), suggesting that asynchronous auditory-visual material may be affecting the social cognitive performance of autistic individuals, including potential gaze bias to the mouth region during social interactions (34). Therefore, a recent version of the MASC was produced with English speaking actors (35), warranting further evaluation of the MASC in an English speaking country such as Australia.

Eye tracking provides quantitative evidence for visual attentional processing (36), offering further understanding of the social cognition processes in autism. Specifically, capturing eye gaze behaviours provides insights into how social information is processed in developing judgements of the internal mental states of others (37, 38). While autistic individuals have demonstrated avoidance of the socially salient areas of social scenes or less at the correct location indicated in a social cognition task (37, 39), no group differences in eye gaze behaviour on the MASC were observed in a previous study involving an adolescent sample (31).

The aim of the present study was to determine the ability of the English version of the MASC to distinguish between autistic adults and non-autistic peers, and examine the visual strategies of both groups during an ecologically valid standardised social cognition assessment. Classification accuracy was assessed by comparing MASC performance with other measures of social cognition and autistic traits, specifically emotion recognition stimuli from the Mind Reading Emotions Library and the Social Responsiveness Scale-2 (40, 41). It was hypothesised that autistic adults would exhibit more difficulties in social cognition on the MASC when compared to a non-autistic control group. It was also predicted that autistic adults, compared to controls would show reduced fixation time towards the social and core facial regions while completing the MASC. The relationship between MASC performance, gaze and intellectual level was also explored. It was expected that MASC performance would be positively correlated with fixation time to pertinent social regions, including the eye and head regions of the MASC characters. Given current understanding of social cognition as a multidimensional construct (30), it was predicted that MASC performance would correlate positively with intellectual functioning (42).

# Methods

## Participants

Autistic participants were recruited via the research contact list of the Curtin Autism Research Group, various autism non-profit organisations throughout Western Australia, universities and social media platforms. Autistic adults were required to have a confirmed diagnosis of Autism Spectrum Disorder under the 4th or 5th versions of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV, DSM-5) (43, 44), including Autistic Disorder, Asperger's Syndrome or Pervasive Development Disorder. Autism diagnosis was confirmed via sighting diagnostic reports. The Social Responsiveness Scale (SRS-2) was completed to assess the extent of autistic like traits (41).

Non-autistic participants were recruited from a large university community network and personal contacts. To determine eligibility, non-autistic participants completed an online screening assessment, consisting of socio-demographic questions and their medical history as well as the online version of the SRS-2. All participants were assessed for general cognitive ability (IQ) using the Wechsler Abbreviated Scale of Intelligence II (WASI-II) (45), and those scoring above the intellectual disability range (IQ >70) were included. Participants were required to have sufficient verbal and written English comprehension. A total of 30 non-autistic adults who completed the screening assessment were included in the study, all scoring below the threshold for clinically significant autistic like traits on the SRS-2. Non-autistic participants were included if they had no previous history of neurodevelopmental or neurological conditions such as cerebrovascular accident, traumatic brain injury or epilepsy.

A total of 60 participants, 30 autistic adults and 30 non-autistic participants completed the study protocol. Five autistic adults were excluded due to IQs <70, or inadequate eye tracking calibration. Five non-autistic participants were excluded due to poor eye tracking calibration. Both non-autistic and autistic participants had comparable age, gender and IQ. The final sample consisted of 25 autistic and 25 non-autistic adults. Table 6.1 summarises the participant's characteristics. This study was approved by the Human Research Ethics Committee at Curtin University, Perth, Western Australia (Approval Number: HR 38/2016).

**Table 6.1. Sample characteristics**

| | Autistic adults (*n* = 25) | Non-autistic adults (*n* = 25) | *p*-value* |
|---|---|---|---|
| | Mean (SD) | Mean (SD) | |
| Mean age (years) | 23.58 (5.73) | 25.88 (7.28) | 0.16 |
| Gender (male/female) | 15/10 | 13/12 | 0.57 |
| SRS Raw Score | 85.71 (30.36) | 40.88 (16.68) | <0.01 |
| Verbal IQ | 103.42 (16.95) | 104.28 (13.67) | 0.85 |
| Performance IQ | 109.42 (15.01) | 108.00 (13.38) | 0.91 |
| Full IQ | 107.13 (15.94) | 106.68 (13.17) | 0.92 |

Note. SD, Standard deviation; SRS, Social Responsiveness Scale; IQ, Intellectual functioning. **p*-value < 0.05.

# Measures

## *Wechsler Abbreviated Scale of Intelligence (Second edition)*

The Wechsler Abbreviated Intelligence Scale (WASI-II) (45) provides a measure of general intellectual ability. The WASI-II measures verbal and non-verbal abilities. Verbal reasoning abilities are evaluated using the Vocabulary and Similarities subtests. The Block Design and Matrix Reasoning subtests provide a nonverbal perceptual reasoning score.

## *Social Responsiveness Scale (Second edition)*

The Social Responsiveness Scale (41) is a measure of autistic like traits. The Adult Self-Report SRS-2 form was administered in this study, consisting of 65 questions rated on a four-point Likert scale (not true '0' to almost always true '3', maximum raw score of 195). The SRS generates scores corresponding to five subscales, social awareness, social cognition, social communication, social motivation and restricted interests and repetitive behaviour. Individuals scoring above a T-score of 59 or a raw score of 68 are suggestive of clinically significant autism traits. Raw scores were reported in this study. The SRS-2 previously demonstrated high correlation with DSM-5 autism diagnostic criteria and cross-cultural validity (46, 47).

## *Movie for the Assessment of Social Cognition*

The Movie for the Assessment of Social Cognition (MASC) (30, 35) is a naturalistic social cognition assessment of emotion recognition and theory of mind abilities, portraying a 15 minute social gathering between four young adults. The film scenarios depict four main characters, two males and two females gathering together for dinner. The storyline captures dating and friendship social themes. The film is segmented into 43 videos, each followed up with a multiple choice question with four options pertaining to the character’s emotions, thoughts or intentions. One video was followed up with two multiple choice questions. The MASC videos are between three to 78 seconds in duration. One of the four multi-choice options is the expected social cognition answer, reflecting intact mentalising ability (48). The remaining three incorrect options are graded and categorised into ‘hyper-mentalising’, ‘hypo-mentalising’ and ‘concrete’. A hyper-mentalising response represents excessive mentalising interpretation, but misjudgement of the intensity and context of the social scenario. Hypo-mentalising demonstrates lower social complexity, indicating insufficient mentalising abilities, including literal interpretation and irony. Concrete options contain no mentalising components. All video segments are followed by the presentation of a single question, with the exception of one video containing two questions. Twenty questions directly relate to affective social cognition, with questions enquiring the character’s emotions (e.g. What does Sandra feel?) or thoughts (e.g. What does Michael think that Cliff is laughing about?). The remaining 24 questions are classified as ‘cognitive’ social cognition, enquiring about the characters ‘intention’ (e.g. Why does Michael say this?).

### *Facial emotion recognition*

The Mind Reading Emotions Library (MR) is a standardised collection of three to seven seconds videos of facial expressions (40). The MR videos had a neutral white background and portrayed actors' dynamic facial expressions with both head and shoulder regions visible. A subset of 40 emotions videos were selected from the library for an assessment of facial emotion recognition. The selected stimuli battery consisted of actors with equal representation of ethnicities, displaying various emotional concepts. The battery included an equal number of positive and negative complex facial emotions counterbalanced for gender. Each video was preceded by a fixation cross presented for one second. Following the presentation of the video, participants were presented with a four option multiple choice question, asking participants to choose the option that best represents the emotion in the video. The MR videos were presented randomly and participants were given a 10 second time limit for each question.

## Eye tracking

Eye tracking data was recorded using a non-invasive remote eye tracker developed by SensoMotoric Instruments (SMI) in a sampling rate of 60Hz. Eye fixation was detected using a dispersion based algorithm. Data acquisition was managed by the SMI iViewX system, utilising a dark pupil detection system and automatic compensation of head movements. This eye tracker provides a gaze position accuracy of <0.4 degrees within a tracking range of 40cm x 20cm at a distance of 70cm. The iViewX system is synchronised with SMI Experiment Centre, software for managing stimuli presentation. The MASC was presented in 1920 x 1080 pixels on a 22 inch computer screen.

## Procedure

After confirming consent, participants were requested to complete an online questionnaire consisting of screening assessments sent via email prior to attending the face-to-face trial at the university laboratory. This study was part of a larger experimental trial, collecting various emotion recognition assessments in parallel with eye tracking and electroencephalogram. The MASC was always administered as the first assessment, as a strategy to minimise fatigue effects. Participants were seated on a stationary height adjustable chair, in front of a 22-inch computer screen of which the MASC was presented. Prior to commencing the MASC, participants were oriented to the eye tracker and a five point calibration was administered. Verbal and visual instructions were provided in accordance with the MASC manual. Participants were introduced to the four main characters in the MASC, and requested to reflect on their emotions and thoughts at the end of each video segment. The MASC multiple choice question was presented immediately following each video segment, with participants asked to indicate their answer on a keyboard. Response time was not prioritised in this trial, hence no time restriction was specified. Following completion of the MASC, participants were invited to take a short break, followed by completion of the Facial Emotion Recognition Task.

## Data preparation

Behavioural data output was derived from SMI BeGaze software. The total number of correct responses on the MASC was calculated, representing social cognition accuracy. The maximum accuracy score on the MASC is 44. Similarly, the number of incorrect responses was added, indicating the total number of selecting hyper-systemising, hypo-systemising and concrete responses. Area of interests were defined using online automatic detection software (49-51), producing the coordinates of the characters' facial areas (eyes, nose and mouth), head and body in each frame of the MASC videos. The areas classified outside of these pre-defined areas were classified as 'other'. Raw fixation data was obtained from the iViewX data file for further analysis. Participants with calibration data above the 1.5 degree visual angle were excluded from the final analysis. Python Version 3.7.4 matched eye fixation data with the dynamically defined areas of interests. Percentage fixation times for the defined areas of interests were calculated for each MASC video, by summing the total fixation time of each area of interest divided by each participant's total fixation time. Final behavioural and eye tracking data output was analysed using SPSS Statistics Version 26.

# Statistical analysis

Data normality was analysed using the Kolmogorov-Smirnov test. Depending on the normal distribution of the data, a non-parametric Mann-Whitney U test or parametric independent *t* test was used to compare the age and intellectual ability composite scores. Distribution of gender between groups was analysed using the chi-square test.

One way analysis of variance (ANOVA) examined the group differences in social cognition accuracy. Given that the incorrect responses were not normally distributed, analysis of incorrect responses was conducted using the Mann-Whitney U test. Receiver operating characteristic (ROC) curves were developed for determining the classification accuracy of the MASC compared to the MR accuracy scores and SRS-2 raw scores. Area under the ROC curve (AUC) value over 0.90, between 0.70-0.90 and 0.50-0.70, suggests high, moderate and low classification accuracy (52). Factorial repeated measures ANOVAs were conducted to analyse the group differences in percentage fixation time. The Greenhouse-Geisser correction was applied where data indicated a violation in sphericity. Effect sizes, partial eta squared ($\eta 2$) were reported and statistical significance was defined as an alpha value, $\alpha < 0.05$. Statistically significant interaction effects were followed up with Bonferroni corrected pairwise interactions.

To explore the potential association of social cognition ability with intellectual functioning and fixation time, Pearson's or non-parametric Spearman's correlations between the social cognition accuracy (overall accuracy, affective and cognitive scores), WASI-II composite scores (overall, verbal and performance) and fixation time area of interests (head, body, others, eyes, nose, mouth) were conducted.

# Results

## Social cognition accuracy

Analysis of overall social cognition accuracy indicated a significant group difference between autistic and non-autistic adults (Table 6.2), $F(1, 48) = 12.78$, $p < 0.01$. Autistic adults had more difficulties in inferring mental states in the MASC compared to the non-autistic group. Analyses of the MASC subtests were statistically significant, indicating the autistic group had lower affective, $F(1,48) = 10.57$, $p < 0.01$; and cognitive, $F(1, 48) = 10.86$, $p < 0.01$; MASC accuracy.

**Table 6.2. Group comparisons of overall accuracy, affective and cognitive MASC accuracy**

| MASC | Autistic adults (*n* = 25) | Non-autistic adults (*n* = 25) | *p*-value* | Partial eta |
|---|---|---|---|---|
| Overall accuracy | 29.68 (6.09) | 34.72 (3.55) | <0.01 | 0.21 |
| Affective accuracy | 13.56 (2.62) | 15.76 (2.15) | <0.01 | 0.18 |
| Cognitive accuracy | 16.12 (3.85) | 18.96 (1.93) | <0.01 | 0.19 |

Note. MASC, Movie of the Assessment of Social Cognition.**p*-value < 0.05

Analyses of incorrect responses were conducted using Mann-Whitney U test. The autistic adults selected more ‘hyper-mentalising’ ($M_{total}$, Autism = 6.08; Non-autistic = 4.4, $p = 0.03$) and ‘hypo-mentalising’ ($M_{total}$, Autism = 4.56; Non-autistic = 2.32, $p < 0.01$) incorrect responses compared to the non-autistic adults. No significant group difference was found for the concrete responses ($M_{total}$, Autism = 3.56; Non-autistic = 2.44, $p = 0.16$).

## Classification accuracy

Figure 6.2 presents the ROC curves for the MASC compared to the MR and SRS-2 measures. The MASC demonstrated a larger AUC value compared to the MR, indicating that the MASC is a better at discriminating between autistic from non-autistic adults compared to the MR measure

(MASC, AUC = 0.72; MR, AUC = 0.61). The SRS-2 achieved the highest AUC value of 0.92.

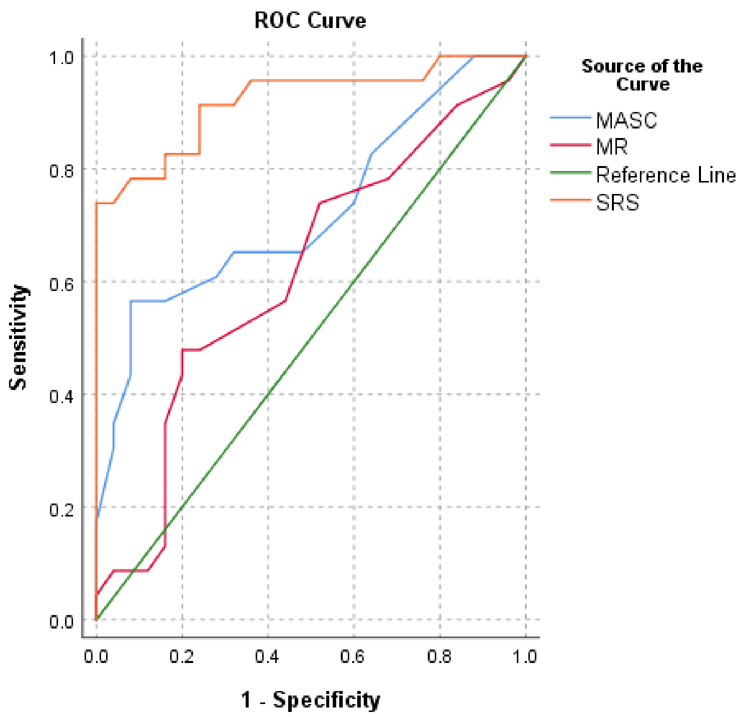


**Figure 6.2. Receiver operating characteristic (ROC) curves for the Movie for the Assessment of Social Cognition (MASC), Mind Reading Battery (MR) and Social Responsiveness Scale-2 (SRS).**

# Percentage fixation time

Table 6.3 summarises the group comparisons of percentage fixation time. Percentage fixation time analysis for group (autistic vs non-autistic) and three area of interests (head vs body vs others) was conducted. The Mauchly's Test indicated a violation of sphericity, $\chi^2(2) = 51.72$, $p < 0.01$, hence a Greenhouse-Geisser correction was applied. There were no significant differences in fixation time between groups, $F(1, 48) = 72.38$, $p = 0.21$. Results revealed a main effect of area of interest, $F(1, 57.58) = 561.21$, $p < 0.01$, and more importantly a group by area of interest interaction effect, $F(1, 57.58) = 5.48$, $p = 0.02$. Follow-up pairwise Bonferroni corrected comparisons indicated that autistic adults gazed less at the head region ($p = 0.02$) and more at non-social regions ($p = 0.04$) compared to non-autistic adults (Figure 6.3). There was a non-significant trend for body region

($p$ = 0.06), with increased gaze towards the body observed for the autistic group.

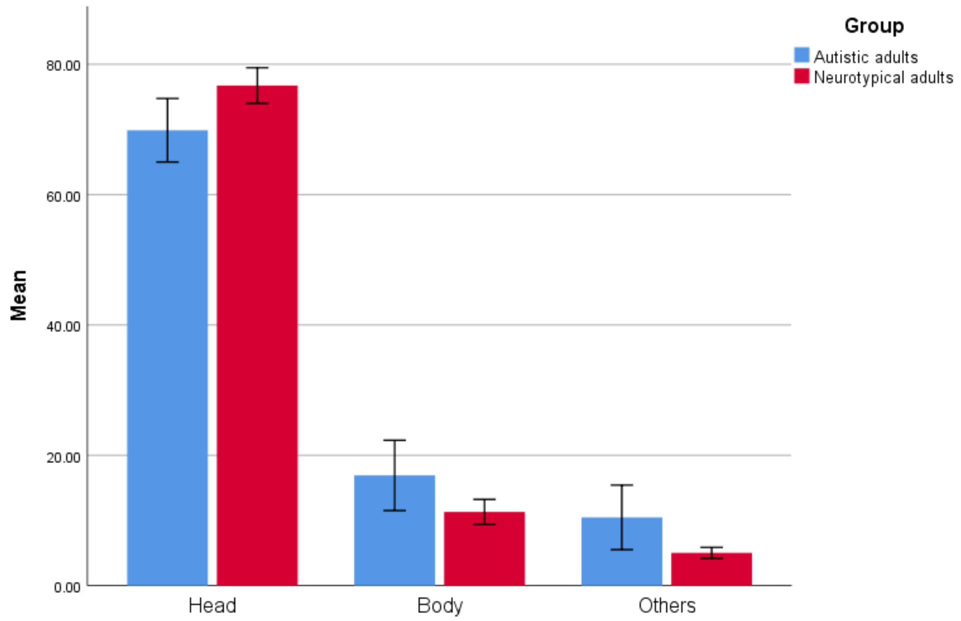


**Figure 6.3. Average percentage fixation time across area of interests, head, body, and others in the autistic and non-autistic adults.**

Percentage fixation time for facial regions were analysed comparing the group (autistic vs non-autistic) and three area of interests (eyes vs nose vs mouth). Violation of sphericity was observed, $\chi^2(2) = 23.34$, $p < 0.01$ and Greenhouse-Geisser correction was applied. Overall fixation time to the facial regions did not differ between groups, $F(1, 48) = .49$, $p = 0.47$. While analysis indicated a significant main effect of area of interest, $F(1, 68.99) = 14.60$, $p < 0.01$, the interaction of group by area of interest was not significant, $F(1, 68.99) = 0.79$, $p = 0.42$.

**Table 6.3. Group comparisons of percentage fixation time while viewing the MASC**

| Area of interest | Autistic adults | Non-autistic adults | |
|---|---|---|---|
| | Mean (SD) | Mean (SD) | *p* value |
| Whole scene | | | |
| Head | 69.87 (12.19) | 76.73 (6.82) | 0.02 |
| Body | 16.91 (13.48) | 11.32 (4.76) | 0.06 |
| Others | 10.47 (12.38) | 5.03 (2.10) | 0.04 |
| Facial regions | | | |
| Eyes | 23.16 (13.94) | 20.93 (10.11) | 0.52 |
| Nose | 18.74 (11.95) | 19.88 (8.86) | 0.70 |
| Mouth | 13.59 (14.37) | 9.87 (7.60) | 0.26 |

# Relationship between social cognition with intellectual functioning domains

Within autistic adults, the analysis presented in Table 6.4 demonstrates strong positive correlations between the social cognition accuracy on the MASC and overall intellectual functioning scores, including Verbal and Performance IQ. There were no significant associations between the MASC and intellectual functioning scores observed in the non-autistic group (Table 6.4).

**Table 6.4. Correlations of social cognition accuracy on the MASC with intellectual functioning scores**

| | WASI Overall IQ | WASI Verbal IQ | WASI Performance IQ |
|---|---|---|---|
| Autistic adults (*n* = 25) | | | |
| Overall MASC accuracy | 0.73** | 0.69** | 0.70** |
| Affective MASC accuracy | 0.66** | 0.62** | 0.65** |
| Cognitive MASC accuracy | 0.71** | 0.67** | 0.67** |
| Non-autistic adults (*n* = 25) | | | |
| Overall MASC accuracy | 0.29 | 0.32 | 0.19 |
| Affective MASC accuracy | 0.30 | 0.25 | 0.29 |
| Cognitive MASC accuracy | 0.19 | 0.31 | 0.03 |

Note. IQ, Intellectual Quotient; MASC, Movie for the Assessment of Social Cognition; WASI, Wechsler Abbreviated Scale of Intelligence. ***p* < 0.01.

# Relationship between social cognition with fixation time

Within the autistic group, a moderately positive correlation was found between affective MASC accuracy and fixation time to the eyes ($r$ = 0.46, $p$ = 0.02). Correlation analyses for MASC accuracy and other area of interests were not significantly correlated (Table 6.5). Similarly, within the non-autistic group, a moderate positive correlation was observed for the affective MASC accuracy and eye fixation time, but this result achieve borderline statistical significance ($r$ = 0.40, $p$ = 0.05). The non-autistic group revealed no significant correlations between MASC accuracy and fixation time across all area of interests (Table 6.5).

**Table 6.5. Correlations of MASC accuracy with fixation time to the head, body, others, eyes, nose and mouth in the autistic and non-autistic group**

| Fixation time | Overall MASC accuracy | Affective MASC accuracy | Cognitive MASC accuracy |
|---|---|---|---|
| Autistic adults | | | |
| Head | 0.30 | 0.13 | 0.38 |
| Body | -0.32 | -0.19 | -0.33 |
| Others | -0.22 | 0.04 | -0.33 |
| Eyes | 0.29 | 0.46* | 0.18 |
| Nose | -0.04 | 0.05 | -0.10 |
| Mouth | -0.29 | -0.26 | -0.28 |
| Non-autistic adults | | | |
| Head | 0.10 | 0.11 | 0.12 |
| Body | -0.01 | -0.06 | 0.04 |
| Others | -0.12 | -0.13 | -0.14 |
| Eyes | 0.39 | 0.40* | 0.27 |
| Nose | 0.14 | 0.13 | 0.11 |
| Mouth | -0.19 | -0.13 | -0.17 |

MASC, Movie for the Assessment of Social Cognition. *correlation is significant at the 0.05 level.

# Discussion

As predicted, autistic adults demonstrated more difficulties in social cognition on the MASC compared to non-autistic adults. This result is consistent with previous studies evaluating the non-English versions of the MASC (13, 30-32). Findings further suggest that the MASC has the ability to distinguish between autistic and non-autistic individuals on a group level. The social cognition accuracy results on the MASC are aligned with previous research suggesting that autistic adults have difficulties attributing the mental states of others, specifically during naturalistic social interactions (53-55). Social cognition difficulties have been postulated as playing an aetiological role in the social communication and interaction impairments of autistic individuals (56), and as at least in part contributing to lower social participation outcomes for autistic adults (57).

Further analysis of incorrect responses revealed increased selection of ‘hyper-mentalising’ and ‘hypo-mentalising’ options in the autistic adults compared to non-autistic controls, while no group differences were observed for ‘concrete’ responses or incorrect options indicative of absence of social cognition components. ‘Hyper-mentalising’ and ‘hypo-mentalising’ responses suggest spontaneous responses of over and misinterpretation of mental state reasoning, respectively (48). Increased selection of hyper and hypo mentalising responses suggest that while autistic adults have awareness of the mental states of others in general, they may have difficulties in accurately interpreting the intensity and contextual nuances of the situations depicted in the MASC, and as a result more frequently selected the ‘hyper’ and ‘hypo’ mentalising options. Findings suggest that autistic adults do demonstrate some social cognition capabilities, disputing the universal social cognitive deficit paradigm in autism (58). However, autistic adults likely experience underlying social cognitive difficulties, resulting from the increased effort required to integrate and appraise the contextual clues presented in scenarios resembling naturalistic social situations (59, 60).

The social cognition difficulties autistic participants elicited by the MASC in the present study likely pertains to the MASC's high levels of ecological validity and task demands, drawing on dynamic audio-visual scenarios depicting age-appropriate real life social interactions such as dating and friendships (30). The ROC curves demonstrated that the MASC was a more sensitive measure compared to an emotion recognition assessment, utilising stimuli containing dynamic facial expressions. The ecological validity of the MASC avoids many of the noted limitations other assessments have shown including clear ceiling effects (23, 24). Social cognition tasks utilising naturalistic and unstructured contexts demonstrated more sensitivity in detecting the subtle social cognitive difficulties of autistic individuals compared to static stimuli (17, 53, 61). Additionally, the MASC permits more nuanced assessment of social cognition via systematically evaluating incorrect responses, providing additional understanding of the possible mechanisms underlying mentalising difficulties of autistic adults, rather than specifically determining the presence or absence of social cognition deficits in autism.

Consistent with the *priori* hypothesis, autistic adults demonstrated altered gaze behaviour during the MASC, with reduced fixation to the head and increased gaze to the non-social regions including extraneous objects observed when viewing the MASC. These findings corroborate those of previous studies utilising dynamic videos with at least two characters (39, 62, 63). Results suggest that increasing fixations to the head region may possibly provide additional opportunities for non-autistic adults to extract meaningful social cognition cues (64, 65), hence facilitating their MASC performance in this study. Further, increased gaze to non-socially salient areas in social interactions suggest difficulties in distinguishing socially relevant salient stimuli or increased saliency of objects for autistic individuals (63, 66). Another explanation suggests autistic individuals have difficulties sustaining their attention towards socially salient areas, e.g. the face, likely contributing to the hyperactive responses observed in neuroimaging studies (67-69).

Interestingly, lower gaze behaviour to the head region was observed in combination with non-significant gaze differences to the core facial regions. The present findings are consistent with a previous study evaluating the gaze behaviour in autistic adolescents during the MASC (31). While the lack of group differences in gaze to the core facial regions may have been unexpected in light of the previous literature exploring eye gaze behaviour in autism, comparable gaze behaviour among autistic and non-autistic have previously been reported, with age and higher intellectual functioning being factors possibly facilitating performance (70, 71). A recent meta-analysis postulated that the presence of movement and sound in dynamic audio-visual social stimuli may be a facilitator in directing autistic individuals attention towards socially salient regions (66). Taken together, both development and stimuli characteristics may partly explain the lack of between group differences in gaze-based behaviours towards the facial regions.

Correlation analysis of fixation time and social cognition performance revealed significant positive associations between affective MASC scores and eye duration. The eyes can be perceived as a highly expressive communication tool, providing mental state information through gaze direction or facial movements (72, 73). Previous studies have reported that increased fixation time to the eyes was associated with improved social cognition performance of autistic adults (31, 74). However, p revious studies have demonstrated fixating on the eyes may not necessarily be indicative of meaningful interpretation of social cues in the autistic group (71, 75). In fact, many autistic individuals reported understanding the importance of eye gaze in social interactions, but demonstrated an eye gaze aversion since it often evokes heightened and negative physiological responses (68, 76).

Results of the present study suggest that higher intellectual functioning is associated with improved MASC scores in the autistic adults group, but interestingly this finding was not observed in the non-autistic group. Findings suggest autistic and non-autistic adults employ different processing strategies during mentalising tasks, specifically autistic individuals requiring more effortful cognitive strategies relative to non-autistic controls when processing social cognition cues (77, 78). Non-autistic individuals adopt more spontaneous mentalising abilities, hence possibly requiring less extensive utilisation of cognitive strategies when processing social cognition interactions (77, 79).

Intellectual functioning was discussed in previous studies as a factor possibly explaining the discrepancy between observed non-autistic gaze behaviours and social cognition difficulties (42). Recent studies have found that autistic individuals, especially those with higher verbal functioning adopt compensatory mechanisms in social interactions, relying on intellectually conceived learnt behaviours to conform into non-autistic social norms (42, 80). In some contexts, adopting compensatory mechanisms may facilitate autistic individuals in problem solving social cognition tasks, but their success may rely on the individual's capacity to meaningfully extract and interpret the information received (81). Within the context of the MASC, autistic adults may have previously learnt normative social behaviours such as directing their gaze to the eyes, but continue to experience difficulties in successfully extracting the key information, necessary for inferring the characters' mental state.

The current study evaluated the MASC an ecologically valid measure to assess the social cognition skills of autistic adults. Results suggest that MASC is a sensitive tool to provide a further understanding of autistic adults' social cognition skills, specifically within the context of interpersonal relationships. This study further provides crucial information relating to appropriate measures for assessing the potential for social emotional interventions to improve autistic adults' generalisation of skills to everyday environments.

The limitations of this study should be considered when interpreting the results. While post-hoc power analysis revealed that the sample in this study was adequately powered to detect differences between autistic and non-autistic adults (Cohen's $d$ = 1.01, with 80% power and $\alpha$= 0.05), larger samples sizes may be required for detecting small group differences in some eye tracking measures. Additionally, the participants in this study were relatively homogenous, consisting of autistic adults with higher intellectual functioning. Given the variability in social cognition performance reported in autistic individuals, future research with larger sample sizes could consider subgroup analysis such as differentiating individuals with different demographic and gaze behaviours to further understand the social cognition profiles across the autism spectrum.

# Conclusion

This study directly compared the performance of autistic and non-autistic adults on the English version of the MASC, a naturalistic assessment for social cognition skills. The MASC was able to distinguish between groups of autistic and non-autistic individuals, with autistic adults demonstrating more difficulties in social cognition. Both verbal and non-verbal intellectual functioning were associated with higher social cognition abilities in the autistic group only. Additionally, eye tracking analysis revealed some differential patterns of fixation towards the head and non-social regions of the MASC stimuli in autistic adults but no group differences were observed in the core facial regions. Fixation time outcomes were not significantly associated with social cognition performance in both autistic and non-autistic groups. Future research is required to explore the social cognition profiles of autistic adults.

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# Chapter 7 : Development and feasibility of the MindChip$^{TM}$ program

This chapter presents a manuscript that has been accepted for publication in Journal of Autism and Developmental Disorders, **impact factor 2.786**:

**Tang, J. S. Y**., Falkmer, M., Chen, N. T. M., Bölte, S., & Girdler, S. (2020). Development and feasibility of MindChip$^{TM}$: A social emotional telehealth intervention for autistic adults. Journal of Autism and Developmental Disorders. Advance online publication. https://doi.org/10.1007/s10803-020-04592-3

# Author Contribution Statement: Chapter 7

As co-authors of the paper entitled, '*Development and feasibility of MindChip$^{TM}$: A social emotional telehealth intervention for autistic adults*', we confirm that Julia Tang has been the principal research and has made the following contributions:

- Conceptualisation and design of the research;
- Data collection (a research assistant completed the mentoring, while the PhD candidate collected the pre and post test measurements), analysis and interpretation;
- Writing the manuscript and critical appraisal of the findings; and
- Corresponding author for communication with the journal.

Our contribution to the paper was consistent with the role of supervisors and involved the following contributions:

- Assistance with conceptualisation and design of the research;
- Assistance with analysis and interpretation; and
- Review and editing of the manuscript

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|---|---|---|
| Signed: | Marita Falkmer | Date: 28.05.2020 |
| Signed: | Nigel TM Chen | Date: 28.05.2020 |
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# Preface

The eye tracking measurements from Chapter 5 and 6 provided insights into the relevance of targeting gaze patterns to facilitate the social emotional processing of autistic adults. However, the contrasting results between the visual search strategies and social emotional accuracy in Chapter 5 and 6 suggest that reduced visual attention to socially relevant areas may not be underpinning the social emotional difficulties in autistic adults. Instead, autistic adults may employ a variety of strategies in social emotional processing. Additionally, findings from Chapter 5 and 6 further suggest that the MASC compared to the RMFT provides a more appropriate assessment for assessing the distant generalisation outcomes of social emotional interventions.

Collectively, findings from Chapter 5 and 6 informed in the learning content and evaluation of the facilitator mediated component of social emotional CBI for autistic adults. Specifically, the development of the facilitator mediated social emotional component of the CBI, MindChip™ included modules to support the exploration of personally relevant strategies in social emotional processing, rather than explicitly directing gaze to socially relevant areas. Phase 3: Feasibility presented in Chapter 7 firstly integrates the findings discussed in Phase 1 and 2, and summarises the development process of a MindChip™ which was used in conjunction with an existing social emotional program, Mind Reading program. Chapter 7 discusses four theoretical underpinnings for the MindChip™ program, including self-efficacy, self-management, social development theories and person-centred practice. This chapter further evaluated the feasibility and preliminary efficacy of the MindChip™ program combined with the Mind Reading program to support the social emotional skills of autistic adults. Informed by the findings in Chapter 6, the MASC was selected as one of the primary outcomes for the pilot evaluation of MindChip™ and Mind Reading, providing a distant generalisation measure for the study.

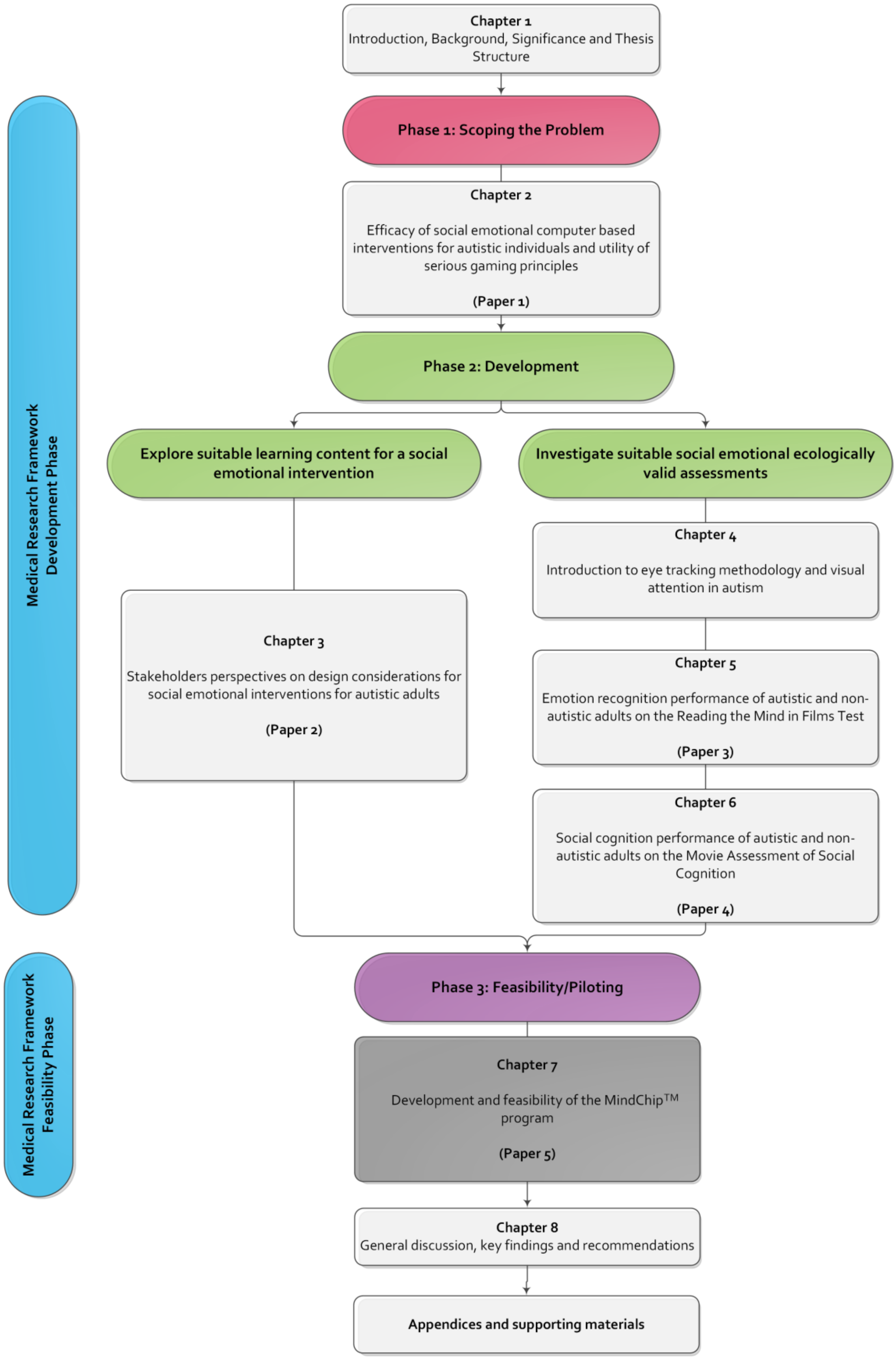


**Figure 7.1. Thesis structure Chapter 7.**

Journal of Autism and Developmental Disorders
https://doi.org/10.1007/s10803-020-04592-3

ORIGINAL PAPER

# Development and Feasibility of MindChip™: A Social Emotional Telehealth Intervention for Autistic Adults

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## Abstract

The study aims to develop and pilot a telehealth social emotional program, MindChip™ delivered with a computer based interventions (CBI) (Mind Reading©) for autistic adults. MindChip™ combined four theoretical perspectives and community feedback underpinning the essential mechanisms for targeting the social emotional understanding of autistic adults. A randomised pragmatic pilot trial (N = 25) was conducted to explore the feasibility of MindChip™ (n = 11) and to understand the preliminary efficacy of combining it with CBI compared to CBI only (n = 14). The use of MindChip™ and CBI combined demonstrated partial feasibility, with preliminary efficacy findings revealing increased emotion recognition generalisation outcomes compared to CBI only. Further research is required to improve the engagement and personalisation of the intervention for autistic adults.

**Keywords** Autism · Computer-based · Emotion recognition · Mentoring · Technology

## Introduction

Social emotional interaction is a process underpinned by encoding and interpreting social cues, informing the generation and evaluation of social responses (Lemerise and Arsenio 2000). Emotion recognition is fundamental to social-emotional reciprocity, depending on multi-modal processing of emotional information from the face, body language and/or verbal intonations to determine the mental states of others (Banziger et al. 2009; Darwin 1965). This process enables adaptive behavioural responses aligned with social situations (Grossmann and Johnson 2007; Lemerise and Arsenio 2000).

Difficulties associated with emotion recognition processing are widely reported amongst autistic individuals[1] (Uljarevic and Hamilton 2013), even when compared with similar conditions (Berggren et al. 2016). These difficulties appear to become more apparent during tasks with increasing complexity such as recognising complex emotions or tasks with restricted response time (Clark et al.

[1] It is acknowledged that person first and identity first terminology has been a topic of considerable debate in the autism community. We understand that these preferences can be dependent on the individual and country. Given that this project is conducted under the Cooperative Research Centre for Living with Autism (Autism CRC), identity first language (i.e. autistic adults) was identified as the preferred terminology. Hence, the term 'autistic adults' was used to align with the preferences of the autism community in Australia.

**Electronic supplementary material** The online version of this article (https://doi.org/10.1007/s10803-020-04592-3) contains supplementary material, which is available to authorized users.

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Published online: 13 July 2020

2008; Harms et al. 2010; Nuske et al. 2013). Challenges in social emotional skills are arguably impacting on the social participation difficulties observed in autistic individuals (Tobin et al. 2014; Williams and Gray 2012).

To date, interventions aiming to remediate the emotion recognition difficulties of autistic adults have employed various modalities, including social skills groups (Spain and Blainey 2015), typically involving small groups of autistic individuals led by a facilitator, focussing on teaching skills, discussions, role playing and individualised feedback (Reichow et al. 2012). While social skills groups demonstrate promising results in improving the social cognition skills of autistic adults, including emotion recognition (Spain and Blainey 2015), most of these groups cover multiple domains of social functioning, limiting the time available for autistic adults to meaningfully absorb the social emotional content (Spain and Blainey 2015). Additionally, social skills groups can be time and resource consuming, with the group context limiting the ability of facilitators to support individualised learning (Rao et al. 2008).

Research has increasingly explored computer based interventions (CBI) as a modality for remediating emotion recognition difficulties in autism (Grossard et al. 2017; Ramdoss et al. 2012). Autistic individuals are widely reported to have a preference for CBI, underpinned by the opportunities it provides for autonomous learning in an environment with minimal distractions (Mazurek et al. 2012; Shane and Albert 2008). While CBI demonstrates effectiveness in remediating emotion recognition difficulties in autism, there is limited evidence demonstrating its efficacy in supporting the generalisation of learnt skills to real world contexts (Ramdoss et al. 2012; Tang et al. 2019a, b). Improving emotion recognition outcomes beyond the training context is arguably essential if these interventions are to contribute to meaningful social functioning changes.

Limited generalisation of skills to everyday social contexts features as a consistent outcome of studies examining the efficacy of social emotional interventions in autism (Fletcher-Watson et al. 2014). It is widely recognised that autistic individuals have difficulties in filtering and coping in everyday situations with high social demands, as a result of their difficulties with multisensory integration (Magnée et al. 2011; Wass and Porayska-Pomsta 2014). While research suggests that autistic adults demonstrate good acquisition of social emotional skills, their difficulties become increasingly more apparent in unstructured social environments (Ponnet et al. 2004; Roeyers et al. 2001; Scheeren et al. 2013). Improving our understanding of those approaches and strategies which facilitate the transfer of emotion recognition skills beyond the training context is key if these interventions are to facilitate meaningful improvements in social functioning.

Research has begun to explore the value of combining CBI for autistic individuals with other intervention approaches including complementing CBI with social skills group training or involving a facilitator as a strategy towards facilitating the generalisation of emotion recognition skills (Lopata et al. 2016; Thomeer et al. 2015). These combined facilitator-mediated approaches generally build on the skills learnt during CBI through analysing facial features and vocal intonation, modelling, imitation and role plays (Russo-Ponsaran et al. 2016). Several interventions have incorporated opportunities for autistic individuals to apply the emotion recognition skills learnt within CBI to everyday scenarios, through analysing feature films or problem solving within a group environment (Golan and Baron-Cohen 2006; Lopata et al. 2016; Thomeer et al. 2015). With facilitator support, providing direct opportunities to practice learnt social emotional skills in naturalistic and unfamiliar settings was discussed as an useful strategy for promoting skill generalisation (Rao et al. 2008). Combining CBI with facilitator-mediated interventions has resulted in greater improvements in emotion recognition skills than participating in social skills group programs alone (Golan and Baron-Cohen 2006; Lopata et al. 2016). However, research examining the potential effectiveness of combining facilitator-mediated approaches with CBI is in its infancy, with further research needed to understand the utility of these approaches in improving the emotion recognition skills of autistic individuals.

Current emotion recognition interventions in autism are generally designed to target children and adolescents, with a paucity of research focussed on designing interventions specifically for autistic adults (Ramdoss et al. 2012). The learning content of existing emotion recognition CBI largely centres on presenting static or dynamic face stimuli, requiring participants to identify emotions in a multiple choice format (Golan and Baron-Cohen 2006; Russo-Ponsaran et al. 2016). However, the learning format and content of these approaches has been criticised as being too simplistic for autistic adults, who would likely require more advanced social emotional content reflecting the complexities of social encounters in adulthood. Understanding the relevance of CBI in improving the emotion recognition skills of autistic adults depends on the evaluation of programs incorporating content more relevant to the social emotional encounters of adulthood.

The aim of this paper is to describe the development process and systematically assess the feasibility of MindChip™ (MC), an online facilitator-mediated program delivered as an adjunct to a CBI targeting emotion recognition skills, Mind Reading© (MR) (Baron-Cohen et al. 2004). The MR program was selected given that it was the only commercially available computer program targeting the emotion recognition skills of autistic adults. The Medical Research Council

Framework for developing complex interventions framed the process of developing MC, outlining an iterative intervention development process for considering the available evidence, theoretical frameworks, community consultation and feasibility and pilot testing (Craig et al. 2013). Areas of feasibility were operationalised based on the focus areas outlined by Bowen et al. (2009), including the (1) preliminary effectiveness of the MC program and CBI on the social emotional outcomes of autistic adults from pre to post intervention, (2) satisfaction of the participants during the MC program and fidelity of the intervention, (3) appropriateness of the MC program prior to further evaluation in a larger experimental trial.

## Design

The development of the social emotional program, MC was guided by the Medical Research Council (MRC) Framework (Craig et al. 2013), with feasibility testing informed by the focus area as described by Bowen et al. (2009). This study was undertaken in three stages. Stage 1, the development of the MC manual, guided by the MRC framework, identifying evidence, theoretical underpinning and modelling process and outcomes. Stage 2, employed a two armed randomised controlled pilot trial examining the feasibility and preliminary efficacy of MC intervention combined with the MR program (Baron-Cohen et al. 2004), in comparison with the MR program only, in targeting emotion recognition skills of autistic adults. Stage 3 revised the MC manual following the results of the pilot study. Figure 1 illustrates the three stages of this study.

### Stage 1: MindChip™ Manual Development

The MC intervention design and modelling involved establishing an evidence base through conducting a systematic review and meta-analysis of the social emotional CBI in autism (Tang et al. 2019a), which also informed the measurement framework for evaluating social emotional interventions in autism. Following the review, two case controlled studies were conducted aiming to evaluate the discriminant validity of two social emotional ecologically valid assessments, the Reading in the Mind in Films test and Movie Assessment of Social Cognition (Tang et al. 2019b; Tang et al. 2020). Focus groups were conducted with 22 stakeholders including autistic youth, allied health professionals and educators, informing the content of the MC manual (Tang et al. 2018). The draft version of the MC manual was reviewed by two autistic adults and pilot tested with one non-autistic individual and two autistic adults prior to conducting the feasibility trial.

## Results

**Identifying the Evidence Base** A literature search was conducted with the goal of identifying existing social emotional interventions for autistic adults. Identified social emotional interventions utilised various modalities in delivering their programs including working with individuals in social skills groups and computer based platforms (Fletcher-Watson et al. 2014; Reichow et al. 2012). While some promising findings emerged in relation to the efficacy of previous social emotional interventions in remediating the social emotional skills in autism, these were limited to improvements in close generalisation outcomes (Ramdoss et al. 2012). An updated systematic review of social emotional CBI in autism, including meta-analysis evaluating the role of serious gaming design principles (Whyte et al. 2015) in moderating the transfer of skills to close and distant generalisation outcomes was conducted (Tang et al. 2019a). Findings revealed that overall existing CBI in autism had rarely engaged or considered the needs of autistic individuals in designing their programs and that incorporating serious gaming design principles improved the efficacy of these programs on distant generalisation outcomes. Combining social emotional CBI with mentoring support was indicated as a likely promising strategy in improving the design and delivery of social emotional interventions, and promoting distant generalisation outcomes.

**Developing Theoretical Underpinnings** Overall findings from the literature review pointed to a need for a social emotional CBI, underpinned by a strong theoretical framework, targeting the needs and aligning with the preferences of autistic adults. In response to this need, the MC program was developed, underpinned by a theoretical framework drawing from self-efficacy, social development, self-management and person-centred practice theories. Underpinning performance mastery, increasing an individual's self-belief in their capabilities in executing an action plan is key in successful goal attainment (Bandura 1986). Within the social development theory, Vygotsky (1978) emphasises the dialectical relationship between the individual and their social environment in promoting learning and development. Addressing both the social and emotional targets of managing a health condition, self-management advocates for approaches which maintain or adjust behaviours and emotional responses to a condition (Corbin and Strauss 1988; Lorig and Holman 2003). Action planning is a core component of self-management, enacted by the process of goal setting, and determining specific steps required in achieving a desired goal (Lenzen et al. 2017; Lorig 2006). Person-centred approaches regard the individuals perspective, values and goals, as central to the decision making process, and key in mitigating against a 'state of incongruence' (Kilbane and

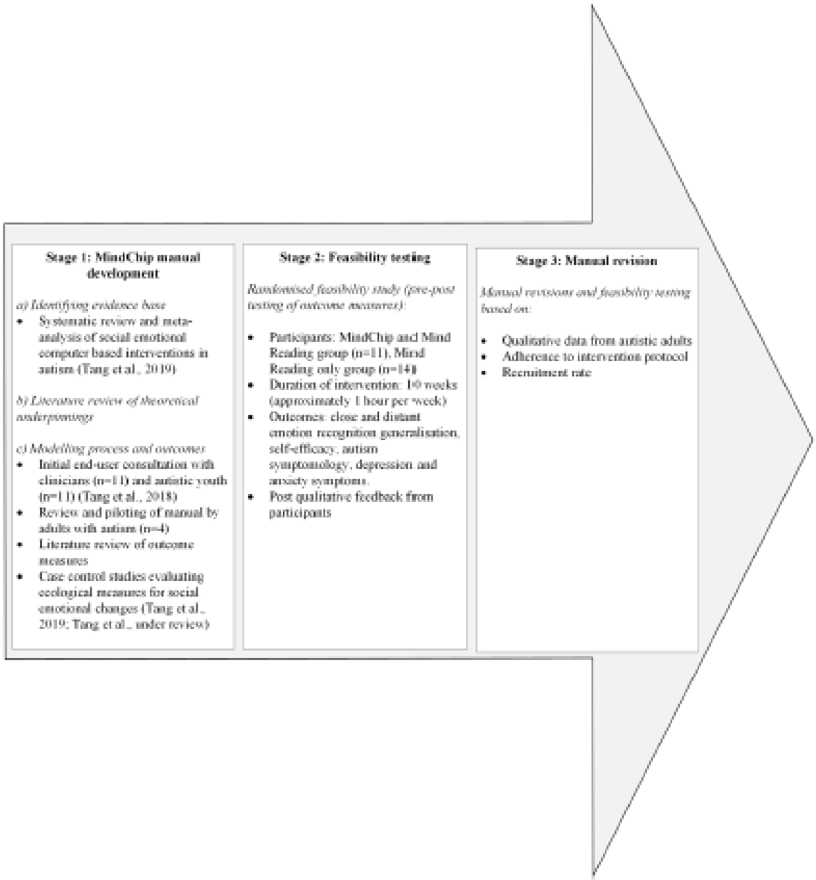



**Fig. 1** MindChip™ development process based on the Medical Research Council Framework for developing and evaluating complex interventions

McLean 2008; Rogers 1957). The key principles of each of these theories and their application to the theoretical framework underpinning the MC program are detailed in Table 1.

**Modelling Process and Evaluating Outcomes** The MRC framework outlines a process for developing interventions, from mapping 'active ingredients' to evaluating outcomes (Craig et al. 2008b; Medical Research Council, 2000). In addition to identifying the relevant literature and theoretical frameworks relating to emotion recognition CBI in autism, consultations with stakeholders were conducted with the goal of obtaining information regarding appropriate content for an emotion recognition program targeting the needs of autistic adults (Tang et al. 2018). Key stakeholders included autism researchers, and clinicians experienced in delivering social skills interventions in autism (n = 11) and autistic youth (n = 11). In summary findings from the focus group study revealed that stakeholders perceived emotion recognition interventions in autism as having two overarching goals, increasing skills and knowledge in understanding and in responding to emotions. The researchers and therapists participating in this study discussed the limitations of existing social emotional interventions, specifically stimuli drawn from static images of facial expressions, valuing interventions addressing integrating emotional cues, such as facial expressions, body language, vocal intonation and the social context. Interventions targeting responding to emotions, developing an understanding of appropriate emotion

Table 1 Application of self-efficacy, social development, self-management and person centred practice in the MindChip™ program

| Theory | Principles and definition | Intervention strategy and application |
|---|---|---|
| Self-efficacy theory (Bandura, 1977, 1986, 1997) | Performance mastery: The impact on previous experiences promoting individual's perceived capability to perform a similar goal | The weekly activities emphasises on exploration of different emotion cues and problem solving strategies<br>Each module is equipped with visual learning tools, including a series of pictures and video based discussions pertaining to the topic, providing safe social emotional learning opportunities<br>The weekly action planning component of the MindChip™ program are structured according to levels of difficulty<br>Participant to set personally meaningful goals according to their comfort levels in their everyday social environments, facilitating the generalisation of skills. Mastery of one difficulty level promotes increased confidence to attempt other goals with increasing complexity and difficulty |
| | Verbal persuasion: the impact of social support and encouragement in enhancing self-efficacy | MindChip™ facilitators can guide participants through the social emotional learning process, providing encouragement in setting realistic goals and exploring new social situations |
| | Vicarious experiences: the influence of observing modelled behaviour on the individual's self-efficacy | Participants are encouraged to observe other individuals within their social networks, increasing opportunities to learn from modelled performance of skills<br>Participants are guided through a structured reflection of their observed experiences, further promoting their social emotional problem solving skills |
| | Physiological responses: Providing effective anxiety and stress management techniques to minimise negative thought patterns and facilitates coping mechanisms and perceived success in their performance | Target exploration of coping tools for managing complex social situations (Mind Reading Toolbox) |
| Social development theory (Vygotsky 1978) | Zone of proximal development: Providing facilitator support, through a collaborative problem solving process and scaffolding to facilitate learning and understanding | MindChip™ participants are encouraged to share their perspectives, and when required facilitators can supplement their knowledge by assisting them to identify new pathways for understanding<br>MindChip™ facilitators utilise participants' unique strengths and knowledge and offering alternative suggestions when necessary |
| Self-management (Lorig and Holman 2003) | Action planning: A process of goal setting and determining specific steps to achieve the desired goal | Weekly action planning component (MindChip™ facilitators encouraged the participant to choose personally relevant goals and trial emotion recognition strategies within their everyday environments)<br>In the Mind Reading Toolbox module, facilitators guide participants to reflect on each social emotional strategy and select those that were personally appropriate and relevant to their lives |

**Table 1** (continued)

| Theory | Principles and definition | Intervention strategy and application |
|---|---|---|
| Person centred practice (Rogers 1957) | Genuineness: Being their own authentic self, rather than maintaining a state of complete façade | MindChip™ facilitators regarded as 'equal partners' rather than 'experts' in social emotional understanding<br>MindChip™ facilitators share their own experiences relating to social emotional discussion topics |
| | Unconditional positive regard: Accepting the individual, without holding judgement despite differences in values and opinions | MindChip™ facilitators guides participants to discover their strengths and difficulties in social emotional skills, acknowledging the uniqueness of each individual |
| | Empathy: Being sensitive to the individual's present feelings | MindChip™ facilitators attentively listen and communicate their understanding about their emotions<br>MindChip™ facilitators engages in active and reflective listening, demonstrating empathy through reserving any judgement and validating their emotions |

responses supported by a 'toolbox' of strategies for managing social situations, were highly valued by both groups. Autistic youth emphasised the importance of embedding motivational aspects in an intervention and linking social emotional content to everyday situations. Drawing from this stakeholder consultation, the intervention objectives of MC were to:

1. create an awareness of the various components necessary in recognising emotions;
2. identify personally relevant strategies for responding to everyday situations where emotion recognition is needed;
3. increase participants understanding of the everyday situations requiring emotion recognition;
4. support participants in creating and identifying opportunities for applying learnt emotion recognition skills to everyday situations; and,
5. foster participants' confidence in managing everyday situations requiring emotion recognition.

**Developing the MindChip™ Manual** Following a systematic review and meta-analysis of the relevant literature (Tang et al. 2019a) and stakeholder consultation (Tang et al. 2018), the MC manual was developed. Four learning tools were developed and embedded into the MC program. The first learning tool, MC describes a computer microchip containing modules pertaining to emotion recognition clues such as eye gazes, face, body, voice and contextual information. The second learning tool, Mind Reading Toolbox describes four different strategies or tools to support problem solving potentially challenging social emotional situations. This includes visual tools, compensatory approaches when a certain emotion cue may be challenging to observe or understand, verbal tools describing using appropriate questions or statements, social tools exploring individual's support network and self-care tools, describing an action or activities to cope with overwhelming situations. The Mind Reading Lightbulb is a five step reflective process on the influence of behaviours on emotions adapted from cognitive behaviour therapy. Finally, the action planning component of the MC program is completed weekly, encouraging participants to observe or practice the social emotional tool learnt in each session. A participant's action plan is then divided into four main levels of difficulty, providing options for selecting goals based on their level of comfort or social emotional level. An example of a level one goal could be observing emotion clues from a video clip, and a goal based in a new or unfamiliar social context is considered as a level four action plan. Figure 2 illustrates the four learning tools of the MC program.

The initial draft of the MC manual was reviewed by two autistic adults considering the aims of the MC program, its

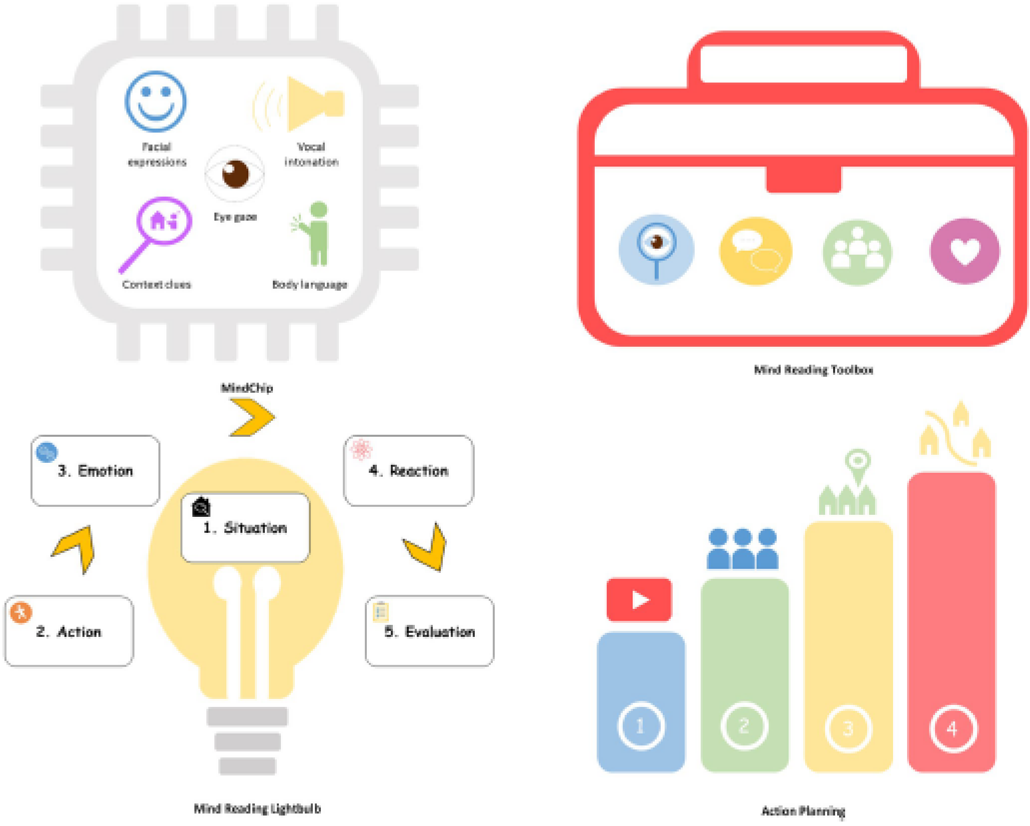



Fig. 2 MindChip™ program learning tools

readability and the appropriateness of the manualised activities. Raising concerns that social skills training programs could be perceived as aligning with the medical model (Kapp et al. 2013), by aiming to impact autistic symptomatology with the underlying aim of 'normalising' an autistic individual, these autistic adults suggested adopting a neurodiversity perspective, acknowledging both strengths and difficulties of the autistic individuals. It was suggested that this approach could be enacted in a program focussing on providing and identifying opportunities for observing typical emotion recognition processes and reflecting on alternative strategies for managing various social situations, rather than overtly teaching emotion recognition skills. Cautioning against presenting characters portraying a stereotypical image of autistic individuals, these autistic adults emphasised the importance of developing a program aiming to support the self-determination of autistic individuals, with the goal of achieving personally meaningful social goals. Achieving these goals was underpinned by an approach considering participants current social preferences and scaffolding current strengths in working towards personal goals.

Pilot testing of the 10 MC sessions with a non-autistic individual revealed a need for increased clarity in presenting aspects of the learning content, particularly in regard to interpreting contextual cues, and using verbal, social or self-care strategies. Further refinements of the manual led to the inclusion of additional visual resources and instructions. Further pilot testing of the MC program with two autistic adults evaluating the depth and acceptability of the intervention content revealed that given the delivery of the program relied on the functionality of a video conferencing platform, it was important to support participants in resolving any technical difficulties as they arose. This testing also highlighted the importance of tailoring MC to individual participants, considering their interest and communication style, in facilitating their engagement.

**Table 2** Modelling of MindChip intervention components and evaluation measures

| MindChip intervention components | Strategies | Measurement |
|---|---|---|
| *Objective 1:* Create an awareness of the various components necessary in recognising emotions | MindChip module | Close generalisation: Mind Reading Emotion Library<br>Distant generalisation: Movie Assessment of Social Cognition |
| *Objective 2:* Identify personally relevant strategies for responding to everyday situations where emotion recognition is needed | Mind Reading Toolbox module | Distant generalisation: Self-efficacy scale |
| *Objective 3:* Increase participants understanding of the everyday situations requiring emotion recognition | Mind Reading Lightbulb | Distant generalisation: Self-efficacy scale |
| *Objective 4:* Support participants in creating and identifying opportunities for applying learnt emotion recognition skills to everyday situations | Action Planning | Distant generalisation: Self-efficacy scale |
| *Objective 5:* Foster participants' confidence in managing everyday situations requiring emotion recognition | Mind Reading Lightbulb<br>Action Planning | Distant generalisation: Self-efficacy scale<br>Transferability: Social Responsiveness Scale, Depression and Anxiety Scales |

**Development of MindChip™ Evaluation Framework** An earlier systematic review and meta-analysis of social emotional CBI in autism informed the development of a measurement framework aimed at evaluating the preliminary efficacy of the MC program (Tang et al. 2019a, b). This review identified three domains relevant to understanding the efficacy of social emotional interventions in autism, close generalisation, distal generalisation and transferability to other skills. Measures assessing aspects of close generalisation were conceptualised as those measuring task performance on emotion recognition stimuli similar to those presented within the intervention. Distal generalisation measures assessed performance of tasks different to those presented within the intervention context, including concepts such as theory of mind and recognition of emotions in realistically depicted scenarios. Measures capturing transferability outcomes evaluated skills or factors beyond the stated focus of the social emotional interventions, such as their impact on autism symptomology (Tang et al. 2019a, b). Table 2 summarises the process of modelling of the intervention objectives to the MC intervention and development of the evaluation framework.

**MindChip™ Content** MC is a 10 week facilitator-mediated intervention, aiming to encourage autistic individuals to observe emotions in everyday social contexts. MC emphasises developing personalised strategies for recognising emotions, rather than correctly identifying emotions per se, targeting 'understanding emotions' and 'responding to emotions' via the MC and Mind Reading Toolbox components of the program, respectively. Following an initial introductory session in week one, the subsequent 5 weeks focus on exploring the 'MindChip' module, comprising of five emotion recognition cues. The remaining 4 weeks cover the 'Mind Reading Toolbox' module, exploring strategies for managing challenging social situations. Prompting personal reflections on recognising emotions, the Mind Reading Lightbulb provides iconic representation of taught strategies. The final week of the MC program supports individuals to reflect on the content of the program and develop a personalised action plan for applying emotion recognition strategies to everyday situations.

Delivery of the MC program was supported by a series of video clips, taken from talk shows or TV shows and static pictorial representations of various emotions. Participants were assigned a mentor acting as a facilitator, supporting participants' mind reading journey, exploring aspects of the MR program, formulating personal goals for observing or practicing emotion recognition strategies aligned with their ability and comfort levels. As a strategy for individualising the MC program for each participant, the facilitator adopted a person-centred approach by enquiring and acknowledging the social emotional strengths of each individual (Rogers 1957). Rather than imposing a set of strategies, the facilitator was encouraged to support the autistic adult to discover their own personally meaningful strategies through enquiring about their own experiences and seeking feedback. Additionally, the selection of picture and video based discussions could be adapted based on the autistic adults' skill level, interests and preferences. Table 3 provides an outline of the MC sessions.

## Stage 2: Feasibility Study

### Methods

**Participants and Recruitment** Recruitment for this study commenced in June 2018 and was completed in March 2019. Participants were recruited via multiple autism organisations and university institutions based in Western Aus-

**Table 3** MindChip™ sessions

| Week | Session focus | Description of session |
|---|---|---|
| 1 | Introduction | Rapport building between facilitators and the autistic adult, general overview of the aims of the Mind Reading and MindChip™ program. |
| 2 | MindChip File 1: Eye guesses | Introduces the concept of linking eye gazes with individual's thoughts and feelings |
| 3 | MindChip File 2: Face clues | Describes observing face clues, such as the eyes, eye brows, mouth and colour of face to recognise emotions |
| 4 | MindChip File 3: Body clues | Describes observing body clues, including head, body posture/distance and hand or arm movements for emotion recognition |
| 5 | MindChip File 4: Voice clues | Introduce the changes in vocal prosody and content in emotion recognition |
| 6 | MindChip File 5: Context clues | Introduce obvious and hidden contextual clues for understanding emotions |
| 7 | Mind Reading Toolbox: Visual strategies | Discuss compensatory visual strategies to recognise emotions |
| 8 | Mind Reading Toolbox: Verbal strategies | Explore verbal strategies, including statements or questions to say when encountering difficult social situations |
| 9 | Mind Reading Toolbox: Social and Self-care strategies | Explore potential support networks and self-care or leisure activities to manage potentially difficult situations |
| 10 | Action Planning | Reflect on previous sessions, discuss most useful tools learnt during MindChip™, and developing an action plan post-intervention |

tralia. Advertising materials such as flyers were distributed via social media platforms, websites and email. Participants were eligible to participate if they were adults aged 18 years and above, residing in Western Australia, with sufficient English language and computer skills to use the MC and/or MR program. Participants were required to have a formal clinical diagnosis of Autism Spectrum Disorder under the Diagnostic and Statistical Manual of Mental Disorders, fifth edition (DSM-5) (American Psychiatric Association, 2013) or Autistic Disorder, Asperger's Syndrome, or Pervasive Developmental Disorder- Otherwise Not Specified (PDD-NOS) diagnoses specified in the Diagnostic and Statistical Manual of Mental Disorders, fourth edition (DSM-IV) (American Psychiatric Association, 1994). Participants were required to have a stable medication regime, i.e. have not recently commenced taking new medication, nor have participated in a social skills intervention in the last 3 months. Participants were excluded if their intellectual functioning was assessed as less than 70 on the Wechsler Abbreviated Scale of Intelligence, second edition (WASI-2) (Wechsler 2011) on the Verbal Comprehension and Perceptual Reasoning Index domains or they reported a recent neurological disorders and/or an acute mental health condition, including epilepsy, stroke, traumatic brain injury, bipolar disorder and personality disorders.

**Ethics** Ethical approval for this study was obtained from the University Research Ethics Board with the protocol registered with the Australian and New Zealand Clinical Trial Registry.

**Demographic and IQ Data** Baseline characteristics of participants were obtained via an online questionnaire requesting participants' demographic information, employment status and computer gaming experience. The WASI-2 was administered to obtain baseline estimation of general intellectual capacity. The WASI-2 contains four subtests, with the Block Design and Matrix Reasoning combined providing a Perceptual Reasoning Index, and the Vocabulary and Similarities, providing a Verbal Comprehension Index score. The WASI-2 demonstrated strong validity and excellent internal consistency, ranging from 0.90 to 0.92 (McCrimmon and Smith 2013).

**Feasibility Related Measures** The feasibility of the MC program was assessed against the key feasibility focus areas as outlined by Bowen et al. (2009), assessing the acceptability, demand, implementation, practicality, adaptation, integration and expansion and preliminary efficacy of the intervention. Intervention satisfaction was evaluated using a questionnaire (Appendix A), scored on a Likert scale ranging from 1 (strongly disagree) to 4 (strongly agree). The questionnaire included some open-ended questions relating to their experiences with the program and suggestions for improvement. The Serious Game Scale (Appendix B) was developed to evaluate participants' level of agreement of the MR program in applying the five serious game principles outlined in Whyte et al. (2015). Intervention fidelity was assessed using checklists completed by the facilitator, covering the core elements of the MindChip™ program such as resources, recap, weekly content and action plans. Table 4 outlines the data collection methods aligned with each key feasibility focus areas.

**Efficacy Related Measures** Assessment of the efficacy of the MC and MR programs was assessed on two main pri-

**Table 4** Feasibility methodology based on the focus areas outlined by Bowen et al. (2009)

| Area of focus | Methodology |
|---|---|
| Acceptability | Satisfaction questionnaire measuring level of agreement on a four point Likert scale (1 = strongly disagree, 2 = disagree, 3 = agree and 4 = strongly agree) |
| | Serious Game Scale, measuring participants' perspective on the serious game features of the Mind Reading© program |
| | Open-ended questions, obtaining feedback from participants |
| Demand | Recruitment rates |
| Implementation | Treatment fidelity checklists |
| | Supervision meetings conducted on a fortnightly basis |
| | MindChip™ and Mind Reading© adherence |
| | Attrition rate |
| Practicality | Participants' feedback as measured via a 4-point agreement rating scale |
| Adaptation | MindChip™ facilitator's case notes |
| | Participants' feedback |
| Integration and expansion | Economic evaluation of MindChip™ program |
| Limited efficacy | Feasibility randomised controlled trial to assess preliminary efficacy |

mary outcomes, close and distant generalisation (Tang et al. 2019a). Close generalisation was measured via an emotion recognition skills assessment presenting tasks in a format similar to the MR intervention, with distant generalisation measures utilising a stimuli distinctly different to the MR intervention, representing in vivo emotion recognition tasks.

The close generalisation measure for this study was derived from the Mind Reading Emotion Library (Baron-Cohen et al. 2004). This library contains a total of 412 short silent dynamic facial videos classified into 24 emotion groups. A subtest of 40 emotion videos was taken from this library, ensuring an equal representation of gender and ethnicity of actors, and the complexity and valance of displayed emotions. The videos were presented in random order. Following the presentation of each video, a four multiple choice option was presented, with one option representing the emotion portrayed in the video. Multiple choice options were randomly selected from the Mind Reading Battery. Participants were provided with a 10 s time limit to respond to each question. The Mind Reading Battery was administered with EEG and eye tracking measurements.

The Movie for the Assessment of Social Cognition (MASC)- English version is an ecological emotion recognition and theory of mind assessment (Bölte et al. 2014; Dziobek et al. 2006). In this assessment, participants are presented with a 15 min social scenario involving four friends gathering on a Saturday. The scenario is segmented into 43 video segments with each segment immediately followed by a question regarding the character's thoughts, intentions and feelings. Eye tracking measurements were recorded while participants completed the MASC. Previous evaluation of the MASC demonstrates its ability to discriminate between autistic adults and their typically developing controls (Isaksson et al. 2019; Muller et al. 2016).

Secondary outcomes measures pertained to emotion recognition self-efficacy, autistic traits, depression and anxiety symptoms. Emotion recognition self-efficacy was measured using the Emotion Recognition Self-Efficacy Scale (ERSES) (Appendix C), adapted from an existing Self-Efficacy Scale previously employed as an outcome measure for health care interventions (Lorig et al. 1996). This scale evaluates an individuals' self-perception of their knowledge, skills and abilities in recognising emotions. The emotion recognition skills targeted in this scale included identifying specific emotions, emotional cues (face, voice, body posture and contextual cues) and problem solving strategies in social environments. Autism traits were measured using the Social Responsiveness Scale-2 (SRS-2), consisting of 65 questions relating to social awareness, social cognition, social communication, social motivation, restricted interests and repetitive behaviour as measured on a four-point Likert scale (Constantino and Gruber 2011). The DASS provided a self-reported measure of mental health, comprising 42 statements relating to negative emotional states of depression, anxiety and stress (Lovibond and Lovibond 1995). The LSAS provided a self-report assessment of social anxiety across various daily situations (Liebowitz 1987). This assessment describe 24 situations rated on two four-point Likert scales relating to the individual's perception of their level of anxiety (fear) and frequency in avoiding the situation (avoidance). Higher scores on the DASS and LSAS reflects poorer mental health outcomes and increased social anxiety.

**Randomisation** This study adopted an open and pragmatic design. A 1:1 randomisation procedure was used based on an online random number generator allocating participants to either the intervention group (receiving both the MC and MR program) or the control group (receiving the MR program only). As a strategy to minimise contamination between the study groups, participants with familial relations were allocated to the same group (Portney and Watkins 2009). Outcome measures were administered via computer based assessments and online questionnaires.

**Intervention Group** The MC program was run over a 10 week period. Each participant met with a facilitator via Zoom Video Communication for an hour each week over the 10 week study period. The facilitator was a psychologist with 8 years' experience in the area of autism. Before the commencement of the MC program, the facilitator was provided with the manual and the PowerPoint slides and videos pertaining to each session. The facilitator attended a 4 h training session, involving a discussion regarding the overall aim of the program, reviewing the activities of each session, and attended one pilot session.

Participants receiving the MC program were provided with a package, containing a copy of the MR program and a participant workbook. Both paper and electronic copies of the participant workbook were provided. Participants required access to a computer device and an active internet connection. Participants were encouraged to use the MR program for 10 h over the 10 weeks. The hours were tracked using a tracking statistics embedded in the MR program. Technical support was provided with installing the MR program and the video conferencing software, ZOOM, on the participants' personal computers.

**Control Group** Participants allocated to the control group received the MR program only. Initial support was provided to install the MR program. Fortnightly emails were sent to each participant, regarding their progress with the program and any support need relating to the use of the MR program. Participants were encouraged to use the MR program for at least 10 h over the 10 week period, approximating 1 hour of usage per week, as recorded using the inbuilt recording statistics of the MR program.

**Procedure** Participants indicating their interest in the study were provided with a participant information sheet and consent form, with all participants reminded that their participation in the study was voluntary and they had the right to withdraw at any point in time. Following the obtaining of consent, participants were sent a password protected electronic survey link via Qualtrics, containing a demographic questionnaire and the secondary outcome measures of this study. Participants were requested to complete the questionnaire, prior to their baseline assessment at a university research laboratory. At baseline, the primary outcome measures, the Mind Reading Battery and the MASC were obtained during a two and a half hours data collection session. The MASC was always administered first followed by the Mind Reading Battery. The tasks for both assessments were presented on a 22" computer screen with the two WASI-2 subtests administered between each of these assessments. Following the baseline assessment, participants were informed of their group allocation and provided with a brief demonstration of the MR program. Participants allocated to the MC program were given a copy of the MC participant workbook (paper-based and electronic), and a re-occurring weekly booking was made to complete the MC sessions.

Following the 10 week intervention period, participants were contacted and asked to complete the post-test assessment. Participants were requested to again complete the online questionnaire, which included the outcome measures obtained in this manner at pre-test with the addition of a series of open ended questions (Appendix A) aimed at obtaining their experiences and perceptions of the programs. Participants were further requested to specify a time convenient for them to attend a session at the university laboratory to obtain post-test measures of the Mind Reading Battery and MASC. The post-test assessment was scheduled within 2 months after the 10 week intervention period. All participants were provided with a $60 shopping voucher at post-test and allowed to retain the provided copy of the MR program.

**Statistical Analyses** Data was managed and analysed using SPSS Statistics Version 26 (IBM Corp 2016). Kolmogorov–Smirnow test assessed the normality of continuous variables. Baseline differences between groups in regard to demographic variables and outcome measures were compared using independent t-tests for continuous variables and Chi square test for categorical data. The assessment of preliminary efficacy of the combination of the MC and MR program in improving close and distant generalisation as well as the secondary outcomes measures were conducted using a group (MC and MR vs. MR only) by time point (baseline vs. post intervention) factorial repeated measures ANOVA. To account for differences in sample sizes and missing data, the close and distant generalisation accuracy scores were converted to percentages. Effect size calculations were expressed using partial eta squared, $\eta^2$, 0.01, 0.06 and 0.14 indicating small, moderate and large effect size, respectively (Cohen 1988). Alpha levels were applied at $p < 0.05$.

Intent to treat analysis was applied using the Last Observation Carried Forward method, whereby the last observed score was used as post-intervention data, accounting for any missing data resulting from attrition (Streiner 2010). Per protocol analysis used data from participants completing the study as intended. Descriptive statistics summarised the process evaluation measures, evaluating the overall agreement relating to the usefulness, usability and satisfaction of the MC and MR programs. Qualitative feedback was analysed using content analysis using NVivo Version 12.

## Results

A total of 30 individuals expressed their interest in participating in this study and were screened for eligibility. Two participants were excluded due to low intellectual functioning scores and three participants declined to participate in the intervention, due to scheduling commitments and disinterest in participating. Subsequently, 25 participants were randomised to the MR and MC intervention group (n = 11) and the MR only control group (n = 14). Participant enrolment, allocation and dropout rates are illustrated in Fig. 3.

Between group baseline comparisons revealed no significant differences between groups in regard to age, gender, intellectual functioning scores, diagnosis, medication intake, employment status and time spent on computer games per week. The most prevalent comorbid diagnoses were anxiety and depression (n = 6) and Attention Deficit Hyperactivity Disorder (n = 5), and other medical conditions such as asthma and diabetes (n = 4). Table 5 describes the baseline characteristics of all participants. No between group differences were observed on all baseline outcome measures.

**Feasibility Measures** Of the 25 participants completing the baseline assessment, three participants assigned to the MR only group did not complete the intervention as intended due to difficulties with installing the software and disengagement. One participant allocated to the MC and MR group withdrew from the intervention citing time constraints, with another participant allocated to this group completing the intervention as intended but failing to attend the follow up assessment. Overall, only one participant in the MR only arm reported using the program for the suggested 10 h or more, with participants averaging 4.27 h (SD = 5.48) usage, citing technical issues, disinterest in the program and competing commitments as limiting their capacity to complete the suggested 10 h. Participants in the MC and MR group completed the MR program for an average of 6.76 h (SD = 3.76), with two participants completing the program for more than 10 h. Several participants reported encountering difficulties with installing the MR program, heightening frustration with the program. Investigation of these issues revealed that they resulted from software compatibility issues, largely resolved by installing the MR program on a computer with older operating system or via an emulator.

**MindChip™ Program Feedback** A total of 7 participants in the MC and MR group completed the feedback questionnaires. Participants receiving the MC and MR programs agreed that it was realistic to complete the MC program for an hour per week, over 10 weeks. All participants completed all 10 MC sessions, with some sessions rescheduled due to family and university commitments. On average participants completed the MC program within 12 weeks, indicating that the MC program was practicable. While most participants found the Zoom application easy to use (86%), several participants encountered technical issues, resulting from poor internet connection, resulting in video and audio not syncing or in disconnection.

Participants' satisfaction ratings relating to the MC program are outlined in Fig. 4, with all participants (n = 7) agreeing that the MC program was a helpful tool for learning emotions. Eighty six percent of participants in the MC program regarded the MC program as a meaningful and relevant emotion recognition learning tool, finding the content understandable and applicable to everyday life. Participants regarded the video discussions as "fun", finding the Mind Reading Lightbulb a useful tool in facilitating their emotion recognition reflective skills:

> "I found the videos most useful, despite them being exaggerated compared to the real world, because we could explore a whole range of possible interpretations that I wouldn't have thought of, for any of the social incidents shown there." (Participant 15)

Participants agreed that it was helpful to have a facilitator, enjoying the informal nature of the sessions and "sensitive and responsive" approach of the mentor.

> "All in all it remind me of having sessions with a good therapist that could actually help. Yes, at times it was hard, but the mentor did her best to readjust our sessions to my needs and the discussions helped motivate me and to understand the lessons." (Participant 7)

Participants stated that the MC program enabled them to achieve their social emotional goals, increasing their awareness of emotions and social interactions, giving them more confidence in deciphering the subtleties of emotions:

> "I gained more confidence and self-esteem in myself, bringing my 'being hard on yourself' behaviour to a minimum, grasped the concept of others' emotions and make more friends for the future…" (Participant 9)

Overall, 86% of participants agreed that they enjoyed the MC program. However, some participants found some MC content too simplistic, especially during the first few weeks of the program, suggesting future tailoring of content to individual's needs and knowledge:

> "Some of the tools were stuff I already do based on life experience, and did not really add on to what I already

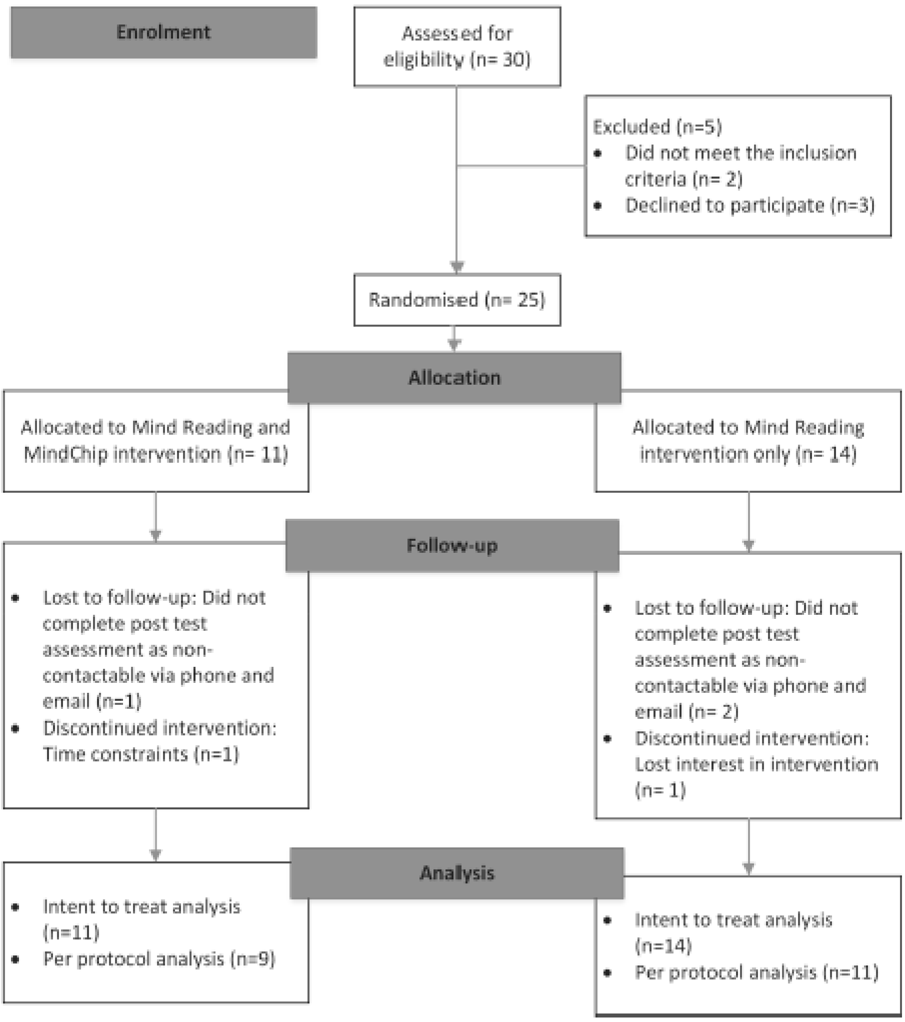



**Fig. 3** CONSORT Diagram for MindChip™ and Mind Reading© feasibility study

knew…. Maybe a test to see where we stand before going over things we actually have a great understanding of already." (Participant 11)

Across the MC sessions, the facilitator achieved 100% fidelity as measured via intervention fidelity checklists. Individual tailoring of sessions included enabling participants to attend the sessions with a support person present (n = 2) and establishing 'ground rules' including ensuring that participants were not interrupted when voicing their opinions. One participant experiencing difficulties in verbally expressing her thoughts opted to use the 'chat' function or instant messaging of Zoom as an alternative communication strategy. Several participants (n = 3) completed some MC sessions via their smart phone rather than on a computer, because of convenience or persistent technical issues (audio not working on computer). The facilitator reported providing regular check-ins and encouraged participants to take micro-breaks during the session as required.

Participants accessed the MC program for a total of 10 h throughout the intervention period. Based on the National Disability Insurance Agency guidelines for funding therapy

**Table 5** Demographic characteristics for intervention and control group

| | Mind Reading© and MindChip™ group ($n$ = 11) | Mind Reading© only ($n$ = 14) | $p$ value |
|---|---|---|---|
| Mean age in years (SD) | 22.64 (6.56) | 25.11 (6.37) | 0.24 |
| Gender (Male/Female) | 7/4 | 9/5 | 0.97 |
| Full-Scale IQ | 110.30 (14.66) | 106.21 (15.35) | 0.52 |
| Performance IQ | 111.20 (14.83) | 110.29 (15.39) | 0.89 |
| Verbal IQ | 107.20 (15.60) | 101.14 (15.73) | 0.36 |
| Autism diagnosis | | | |
| ASD* | 7 (63.6%) | 5 (35.7%) | – |
| High Functioning Autism | 2 (18.2%) | 4 (28.6%) | |
| Asperger Syndrome | 2 (18.2%) | 4 (28.6%) | |
| PDD-NOS* | 0 (0%) | 1 (7.1%) | |
| Other diagnosis | | | 0.74 |
| Yes | 7 (63.6%) | 8 (57.1%) | |
| None | 4 (36.4%) | 6 (42.9%) | |
| Medication | | | 0.90 |
| Yes | 5 (45.5%) | 6 (42.9%) | |
| No | 6 (54.5%) | 8 (57.1%) | |
| Employment status | | | 0.73 |
| Employed | 3 (27.3%) | 3 (21.4%) | |
| Unemployed | 8 (72.7%) | 11 (78.6%) | |
| Time spent on computer games per week (hours) | | | 0.84 |
| 0 | 2 (18.2%) | 3 (21.4%) | |
| ≥ 1 | 9 (81.8%) | 11 (78.6%) | |

*ADD* Attention Deficit Disorder, *ADHD* Attention Deficit Hyperactivity Disorder, *ASD* Autism Spectrum Disorder, *PDD-NOS* Pervasive Development Disorder Otherwise Not Specified

*$p < 0.05$

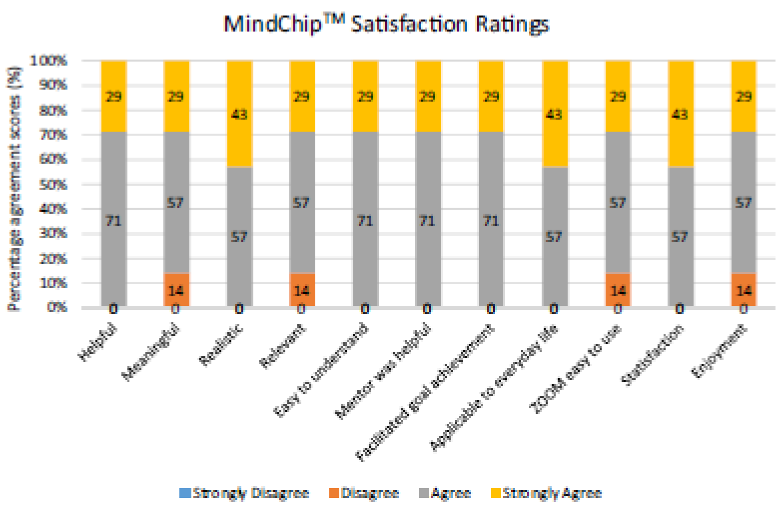



**Fig. 4** MindChip™ satisfaction ratings

sessions for autistic individuals, the cost for an hour MC session for each participant would be about $193.99 Australian Dollars (AUD) (National Disability Insurance Agency 2019a). Each MR program costs $129 AUD, however this program is no longer in production and is no longer stocked by the publisher. Thus, the total cost for each participant receiving both the MC and MR program over 10 weeks was equivalent to $3038.82 AUD.

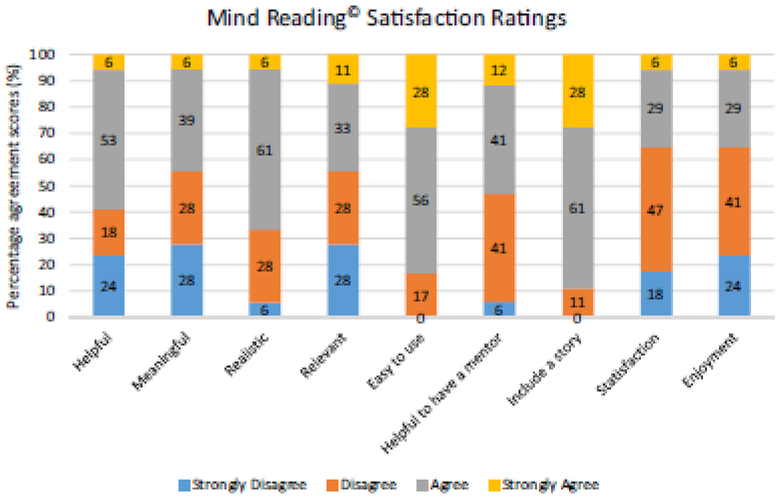



**Fig. 5** Mind Reading© satisfaction ratings

**Mind Reading© Program Feedback** Feedback of the MR program was obtained from participants in both groups (N= 19). More than half (59%) of the participants, including the group receiving both the MC and MR programs agreed that it was helpful, with 44% regarding it as a meaningful and relevant emotion recognition learning tool. The majority of the participants (83%) agreed that it was easy to use the MR program. Most participants (89%) agreed that a story underpinning the MR program would make it more motivating, with half of the participants (53%) agreeing that parallel mentoring support would improve the program. Overall, only 35% of participants were satisfied and enjoyed the MR program. Overall satisfaction ratings of the MR program are shown in Fig. 5. Participants reported technical issues, disengagement with the program and other competing commitments as limiting their capacity to complete the 10 h, suggesting low levels of success rate in implementing the MR program. Two thirds (66%) of participants thought it was realistic to use the MR program for an hour a week, over 10 weeks.

Figure 6 summarise the serious game agreement ratings of the MR program. Only a quarter of participants agreed with the statement that "The MR program was motivating", with most reporting feeling disinterest in completing the activities, likely as a result of the outdated nature of the content and interface:

> "I feel that the characters used in the program are too outdated, along with the rest of the program, to really captivate users or create much motivation to keep exploring it. It is simply too old for today's standards to be regarded as a good way to help people learn emotions." (Participant 18)

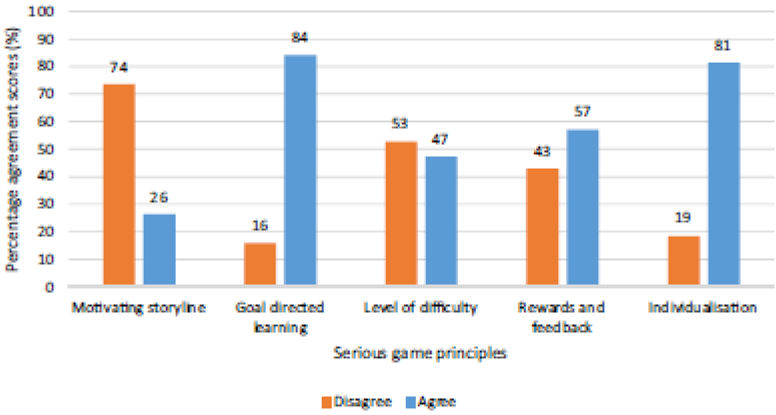
The majority of the participants agreed that the MR program had clearly defined goals (84%) and good individualisation of features (81%), stating the program had "good intentions" and could be beneficial if updated. Participants stated that the goals were "clear and easy to understand", enjoying the flexibility of exploring emotions within the 'Emotions Library' which built their knowledge. Participants valued being able to customise their own quizzes as it gave them some "creative control". However, some participants felt that there was too much information, finding the lack of structure overwhelming:

> "It was too broad. Having too many choices of what to do overwhelmed me. Personally, I feel it would be better to have a standard circuit to work through all the different tasks, rather than being given the option of doing…them all at once." (Participant 22)

Serious Game ratings for the MR program relating to the level of difficulty, rewards and feedback were similar, with agreement scores of 47% and 57%, respectively. While participants reported enjoying the rewards system which involved collecting various items as rewards others found it uninteresting and "belittling". Several participants reported appreciating the robot character guide who provided verbal prompts perceiving it as helpful in guiding them when they were in need of assistance:

> "I do like the timer [in] first initial voice over…hearing a friendly voice at the start played more than once is very good. I also really like it whenever the GUI

**Fig. 6** Mind Reading© serious game agreement ratings




[Graphic User Interface] flashes during a voice over… it's a really effective method for way finding assistance." (Participant 4)

While for some participants the opportunity to reattempt incorrect task enabled them "not dwell on the incorrect answers", others felt that feature increased their frustration:

"I found myself questioning and picking answers at random…when I got it wrong instead of it coming up red and showing me the right way or the right one it would get me to redo it, if I didn't get it the first time I'm not going to get it for the next few attempts." (Participant 23)

Other views included that the MR program was too *"basic"* and that it would be more appropriate to younger participants, that the emotion expressions were too *"exaggerated"* and were an inaccurate portrayal of the emotions. One participant remarked:

"It's unrealistic for people to always react that way … Some of the depictions of specific of emotions were frankly so over the top, if I'd encountered them in public, I'd assume I was being taunted sarcastically." (Participant 28)

Others valued the range of emotional expressions, particularly those embedded within everyday scenarios and depicting more subtle emotions:

"I enjoyed the facial expressions which were somewhat amusing in how over-the-top they were. The more subtle ones were helpful in that they sometimes helped me pick up on things in real people's expressions." (Participant 8)

Overall, participants' satisfaction and level of engagement with the MR program was low. Participants provided several suggestions for adapting the MR program aimed at increasing its relevance to autistic adults including embedding themes relating to 'interface updates', a 'storyline', 'goals', 'rewards and feedback' and 'level of difficulty'. These suggestions are outlined in Table 6 along with exemplar quotes.

**Preliminary Efficacy** Intention-to-treat analyses (Table 7) indicated improvements across close and distant generalisation measures, self-efficacy and reductions in autistic traits over time. Significant group by time point was only observed for distant generalisation measure, $F(1, 193{,}99)=6.80$, $p=0.02$, partial $\eta^2=0.23$, with the group receiving the MC program demonstrating greater improvement in distant generalisation skills from baseline to post-intervention ($p<0.01$). Depression and anxiety outcomes did not reveal a significant main effect over time.

Similarly, on protocol analyses (Table 8) revealed a significant main effect from baseline to post-intervention for close and distant generalisation measures, self-efficacy and autistic trait scores. However, group by time point interactions did not achieved significant differences. Although, a near significant trend was observed for group by time point interaction for distant generalisation skills, $F(1, 135.172)=4.44$, $p=0.05$, partial $\eta^2=0.20$.

## Stage 3: Manual Revision

Stage 3 summarised the main findings from the feasibility study, informing recommendations for revisions of the MC program. Overall, the MC facilitator component of the program was acceptable to participants, but limited adherence was observed for the MR program, suggesting

Table 6 Participants' suggestions for improving the Mind Reading© program

| Mind Reading adaptations theme | Suggestions | Exemplar Quotes |
|---|---|---|
| Interface update | Graphics needs to be updated<br>Ensure compatibility with current operating systems | "Update it so you have it with people who are better at acting the emotions and have a better UI that looks attractive." (Participant 1)<br>"Making a version compatible with modern operating systems." (Participant 8) |
| Storyline | Add a storyline with an overarching theme<br>Integrate real life situations into storyline | "A storyline of some sort could be an effective tool for motivating people to keep using the program every week…It could also be useful for presenting characters that feel like they are there for more than just holding your hand through the program." (Participant 27)<br>"Choose a character and work your way through events that cause different reactions in your character. The 'villains' of the story would have angry/negative expressions, while the 'good' people would mostly have positive emotions" (Participant 22)<br>"I would not like a story because I would find it difficult to take a story about recognising emotions seriously–not that the story has to be a serious one, but it needs to be engaging and integrated into the other activities." (Participant 8) |
| Goals | Focus on strategies to recognise emotions<br>Add context into emotion recognition goals | "Use better acting and/or examples. Instead of just pointing out emotions make lessons to point out the strategies for figuring the emotions" (Participant 7)<br>"Situations involving more prevalent common social issues like high school parties, dating or interaction with authority figures." (Participant 28) |
| Rewards and feedback | Have a clear end reward to work towards<br>Tangible rewards<br>Provide explanation and strategies for incorrect responses<br>Progression log to track areas of strengths and difficulties | "Having a target at end [will] be motivating to work towards –see Carmen Sandiego CDs or Harry Potter game app…certificate is only available at very end" (Participant 15)<br>"I would also appreciate a way to make rewards feel more tangible. Perhaps if they complete a task, a user could receive a desktop wallpaper for their computer or a short video. Something they can access without opening the program so that it feels more like something you can take away with you." (Participant 26)<br>"Only thing that could be improved about the feedback is if there was a small analysis explaining why your answer was correct/incorrect, allowing the person using the program to progress and learn faster." (Participant 18)<br>"Could do with an activity log to chart one's progress (also acts as record/target)… 'My Collection' being general, not telling you which particular sections you've been good at (to more focus your learning)" (Participant 15) |
| Level of difficulty | More levels of difficulty is required<br>Identify random emotions rather than emotions in categories<br>Adding more subtle emotions and providing a description of these clues<br>Providing explanation for emotion recognition strategies | "I would say this may be improved by the addition of a greater difficulty scale that would vary from very outward projected emotion in comparison to very subdued emotion. Maybe with a description of some of the more subtle clues of expression." (Participant 28)<br>"Being able to identify random emotions and having to state how you identified the emotion would've been very helpful" (Participant 11) |

**Table 6** (continued)

| Mind Reading adaptations theme | Suggestions | Exemplar Quotes |
|---|---|---|
| Individualisation | Create more structure but also providing users with the option to skip some activities | "Instead of being forced to choose streams, might be better if the (themed) host guides you through them successively? Otherwise, you risk missing out on certain modules. If an individual wanted to skip these modules, they could just skip it on the singular path" (Participant 22) |

**Table 7** Baseline and post-intervention outcome measures, MindChip™ ($n$ = 11) and Mind Reading© only group ($n$ = 14)

| Outcome | Baseline mean (SD) | Post-test mean (SD) | F value (df) | p value, partial $\eta^2$ |
|---|---|---|---|---|
| Mind Reading Battery % | | | | |
| MindChip™ | 70.95 (13.94) | 77.37 (8.90) | $F_{(1, 7.57)}=0.13$ | $p=0.72$, |
| Mind Reading© | 67.81 (11.77) | 75.84 (11.85) | | $\eta^2=0.01$ |
| Movie Assessment of Social Cognition[a] | | | | |
| MindChip™ | 64.67 (13.38) | 73.35 (12.20) | $F_{(1, 193.99)}=6.80$ | $p=0.02$, |
| Mind Reading© | 70.36 (10.97) | 71.10 (12.56) | | $\eta^2=0.23$ |
| Self-efficacy scale % | | | | |
| MindChip™ | 50.53 (21.83) | 58.07 (21.60) | $F_{(1, 38.95)}=0.83$ | $p=0.37$, |
| Mind Reading© | 63.31 (17.80) | 67.20 (16.03) | | $\eta^2=0.04$ |
| Social Responsiveness Questionnaire | | | | |
| MindChip™ | 87.40 (30.08) | 83.40 (30.41) | $F_{(1, 64.82)}=0.65$ | $p=0.43$, |
| Mind Reading© | 87.29 (31.04) | 78.57 (25.84) | | $\eta^2=0.03$ |
| Depression, Anxiety, Stress Scales (Overall) | | | | |
| MindChip™ | 42.70 (24.71) | 37.20 (24.73) | $F_{(1, 20.37)}=0.17$ | $p=0.68$, |
| Mind Reading© | 35.14 (33.54) | 32.29 (23.85) | | $\eta^2=0.01$ |
| Depression, Anxiety, Stress Scales (Anxiety) | | | | |
| MindChip™ | 12.80 (7.85) | 10.00 (7.87) | $F_{(1, 11.83)}=0.95$ | $p=0.34$, |
| Mind Reading© | 11.00 (12.70) | 10.21 (9.46) | | $\eta^2=0.04$ |
| Depression, Anxiety, Stress Scales (Depression) | | | | |
| MindChip™ | 11.60 (9.17) | 10.50 (8.62) | $F_{(1, 1.61)}=0.07$ | $p=0.79$, |
| Mind Reading© | 8.57 (10.31) | 8.21 (8.16) | | $\eta^2<0.01$ |
| Depression, Anxiety, Stress Scales (Stress) | | | | |
| MindChip™ | 18.30 (9.71) | 16.70 (10.40) | $F_{(1, 0.04)}<0.01$ | $p=0.97$, |
| Mind Reading© | 15.57 (12.21) | 13.86 (8.93) | | $\eta^2<0.01$ |
| Liebowitz Social Anxiety Scale (Fear) | | | | |
| MindChip™ | 39.20 (18.77) | 37.00 (19.01) | $F_{(1, 5.83)}=0.35$ | $p=0.56$, |
| Mind Reading© | 27.21 (18.10) | 26.43 (15.94) | | $\eta^2=0.02$ |
| Liebowitz Social Anxiety Scale (Avoidance) | | | | |
| MindChip™ | 28.13 (16.02) | 24.75 (10.99) | $F_{(1, 11.70)}=0.20$ | $p=0.66$, |
| Mind Reading© | 27.25 (20.35) | 21.67 (18.51) | | $\eta^2=0.01$ |

[a]MASC Scores were converted into percentage accuracy (total number of correct answers divided by number of questions)

limited feasibility in implementing MC in combination with the MR program. Findings suggested that the MC manual could be improved by adding suggestions for individualised tailoring of content, including an assessment of individual social emotional skills and adapting the content based on their perceived skills. Additionally,

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Table 8 On protocol results-Baseline and post intervention outcome measures, MindChip™ ($n$= 9) and Mind Reading© only group ($n$=11)

| Outcome | Baseline mean (SD) | Post-test mean (SD) | p-value (within) | p-value (between) |
|---|---|---|---|---|
| Mind Reading Battery % | | | | |
| MindChip™ | 71.89 (15.16) | 78.59 (6.97) | $F_{(1, 28.79)}=0.44$ | $p=0.52$, |
| Mind Reading© | 66.17 (11.17) | 76.58 (11.87) | | $\eta^2=0.03$ |
| Movie Assessment of Social Cognition* | | | | |
| MindChip™ | 65.40 (14.80) | 73.74 (12.09) | $F_{(1, 135.17)}=4.44$ | $p=0.05$, |
| Mind Reading© | 72.82 (9.68) | 73.76 (11.69) | | $\eta^2=0.20$ |
| Self-efficacy scale % | | | | |
| MindChip™ | 49.89 (18.40) | 60.18 (16.22) | $F_{(1, 40.97)}=1.07$ | $p=0.32$, |
| Mind Reading© | 61.93 (17.67) | 66.88 (15.61) | | $\eta^2=0.06$ |
| Social Responsiveness Questionnaire | | | | |
| MindChip™ | 80.29 (16.83) | 73.71 (14.48) | $F_{(1, 43.69)}=0.35$ | $p=0.56$, |
| Mind Reading© | 94.82 (27.92) | 83.73 (23.45) | | $\eta^2=0.02$ |
| Depression, Anxiety, Stress Scales (Overall) | | | | |
| MindChip™ | 44.14 (22.04) | 33.43 (22.32) | $F_{(1, 107.15)}=0.79$ | $p=0.39$, |
| Mind Reading© | 37.45 (36.46) | 33.82 (24.93) | | $\eta^2=0.05$ |
| Depression, Anxiety, Stress Scales (Anxiety) | | | | |
| MindChip™ | 13.71 (7.54) | 8.57 (7.61) | $F_{(1, 36.71)}=3.12$ | $p=0.10$, |
| Mind Reading© | 11.36 (13.66) | 10.36 (9.68) | | $\eta^2=0.16$ |
| Depression, Anxiety, Stress Scales (Depression) | | | | |
| MindChip™ | 13.00 (9.18) | 10.14 (9.32) | $F_{(1, 12.35)}=0.45$ | $p=0.51$, |
| Mind Reading© | 10.36 (10.99) | 9.91 (8.43) | | $\eta^2=0.03$ |
| Depression, Anxiety, Stress Scales (Stress) | | | | |
| MindChip™ | 17.42 (7.32) | 14.71 (8.10) | $F_{(1, 0.61)}=0.02$ | $p=0.88$, |
| Mind Reading© | 15.73 (12.92) | 13.55 (8.75) | | $\eta^2<0.01$ |
| Liebowitz Social Anxiety Scale (Fear) | | | | |
| MindChip™ | 35.14 (17.48) | 32.29 (17.21) | $F_{(1, 7.38)}=0.33$ | $p=0.58$, |
| Mind Reading© | 29.64 (18.72) | 28.64 (16.13) | | $\eta^2=0.02$ |
| Liebowitz Social Anxiety Scale (Avoidance) | | | | |
| MindChip™ | 26.00 (16.04) | 22.57 (9.83) | $F_{(1, 31.75)}=0.45$ | $p=0.51$, |
| Mind Reading© | 32.33 (20.63) | 24.89 (19.92) | | $\eta^2=0.03$ |

[a]MASC Scores were converted into percentage accuracy (total number of correct answers divided by number of questions)

MC participants suggested permitting access to various methods of delivery such as utilising chat functions or mobile phone access.

## Discussion

This study described the development and evaluated the feasibility and preliminary efficacy of a social emotional online facilitator-mediated program for autistic adults in a pragmatic pilot trial. The MC program was designed to address the gap in existing interventions targeting the social emotional skills of autistic adults, with the specific goal of generalising learnt skills to real life environments (Bishop-Fitzpatrick et al. 2013; Ramdoss et al. 2012; Tang et al. 2019a). Developing interventions has several dimensions of complexity, requiring careful consideration of several interacting components impacting on the standardisation, implementation and acceptability of the intervention at the societal and organisational level (Craig et al. 2008a; Kastner and Straus 2012) The MRC framework provided a useful framework in guiding the development of the MC program, enabling establishment of evidence and theoretical based understanding of the essential ingredients of the intervention, and elucidating potential logistical issues in evaluation (Craig et al. 2008a).

The key feasibility focus areas outlined by Bowen et al. (2009) guided the methodology of the present feasibility study before proceeding to larger experimental trials, mainly (1) participants' satisfaction and perceived appropriateness of the MC and MR programs (acceptability), (2) amount of expression of interests received for the interventions (demand), (3) extend to which the program was delivered in accordance to the manual (implementation), (4) participants' agreement on the ease or difficulty in accessing the intervention (practicality), (5) suggested improvements for the intervention to expand to a larger population (adaptation), (6) perceived fit and expansion of the intervention within the Australian disability system (integration and expansion), and (7) preliminary effects of the interventions (limited efficacy).

Findings indicated partial acceptability of the MC and MR programs. Good engagement was observed for the facilitator-mediated components of the MC program, with participants considering it a useful tool in developing their social emotional skills. In addition, recruitment rates and retention *(demand)* in this study suggest that the MC program was acceptable to the autistic adults. Intervention adherence appeared to improve as a result of a facilitator-mediated approach as participants in the MC program demonstrated higher retention rate (> 80%), and increased MR usage in comparison to the MR program only group. These findings are consistent with previous studies demonstrating the involvement of a facilitator has a positive influence in improving the social relationship outcomes of autistic adults in various settings (Martin et al. 2017; Siew et al. 2017).

In the MC group, the feedback ratings suggest high levels of satisfaction with involving a facilitator in supporting the social emotional learning of autistic adults. However, approximately half of the participants in the CBI only group (53%) stated they would prefer support from a facilitator when completing the MR program. Collectively, findings suggest that autistic adults have divergent social emotional learning preferences, a conclusion supported by the noted variability of functioning profiles in autism (Masi et al. 2017). Future studies could consider embedding specific questions enquiring autistic individuals' social emotional learning preferences prior to commencing an intervention, further enabling evaluation of the acceptability of different approaches in targeting the social emotional skills of autistic adults. Feedback questions could focus on autistic adults' perspectives on the acceptability of the facilitator mediated approach, focus of the program, and willingness to invest in the program itself.

High intervention fidelity suggests ease in implementing the manualised MC content *(implementation)*. Slight deviations from the manual were made in relation to adapting the activities and discussions to align with the interest and goals of the participants, aligning with the principles of the person-centred framework (Rogers 1957). Findings suggested the facilitators' intuitive observation and adaptability in individualising the learning content promoted an engaging and positive learning environment for the participants. There is further scope to improve the individualisation of the MC program, with some participants finding the content covered in the first 5 weeks too simplistic, recommending more personalisation of content based on individuals' knowledge *(adaptation)*. Further work with autistic individuals in co-producing the MC program, including establishing guidelines for individualising and tailoring the content, would likely improve the program. The moderate levels of satisfaction observed for the MR program activities, with participants citing outdated interface and poor integration of serious game elements as main reasons for their disengagement with the program, align with the most recent published study evaluating the MR program (LaCava et al. 2007). Acceptability is likely to improve as a result of integrating more serious gaming principles (Whyte et al. 2015).

Providing teleconferencing option was perceived as a practical option for participants to access the MC intervention, despite the technical difficulties experienced due to limited internet connection *(practicality)*. In Australia, barriers in transportation are prevalent given its widely dispersed population, increasing the cost and inconvenience associated with accessing face-to-face interventions, especially for those living in remote and regional areas (Bradford et al. 2016). Based on the price guidelines established by the National Disability Insurance Scheme in Australia (National Disability Insurance Agency 2019b), travel claims are limited to $58 AUD per hour and to only 30–60 min depending on the individual's geographical location, potentially requiring families to cover these excess expenses. Given MC is delivered via a teleconferencing software participating in the program incurs no travel costs contributing to the cost effectiveness and convenience of the intervention for families and service providers. Issues relating to software compatibility and the low levels of engagement observed among participants in response to the MR program suggest that in its current format, the feasibility and acceptability of this program is limited. Participants receiving the MC program reported some minor technical difficulties, resulting from poor internet connectivity, highlighting the importance of addressing this issue before expanding the reach of the MC program in the Australian context.

Preliminary efficacy results revealed that those receiving the MC program with CBI demonstrated greater improvements on the MASC. This finding suggests the potential for combining a facilitator-mediated approach with CBI for improving distant generalisation outcomes, suggesting an improvement in social emotional skills beyond the specific intervention context, arguably an important outcome in intervention evaluation (Berggren et al. 2018). The other outcome measures assessing close generalisation social emotional skills, self-efficacy, autistic traits and mental health outcomes demonstrated no significant differences between groups. These preliminary findings aligned with those of previous research demonstrating that the MR program contributes to improvements in close generalisation outcomes, consistent with previous studies (Golan and

Baron-Cohen 2006; LaCava et al. 2007) which may reflect a practice effect, given that the assessment stimuli was similar to the intervention itself (Tang et al. 2019a). While further research is needed, these preliminary findings suggest that receiving the combination of the MC and MR programs likely improves the social emotional skills of autistic adults.

As this was the first evaluation of the MC program, this study sought to initially assess the preliminary efficacy of the MC program in comparison to an active control group. Given the initial promising findings of combining the MC program with a CBI, future research may now seek to elucidate the specific mechanisms facilitating the social emotional skills of autistic adults. Future studies could compare the relative contribution of the facilitator-mediated and computer based components of the MC program, and identify the most helpful aspects of the facilitator-mediated approach for autistic adults.

## Limitations

Although the MC program yielded promising feasibility, the small sample size limited the statistical power for formulating definitive conclusions in regard to the relative effectiveness of the intervention arms. Additionally, a single facilitator delivered the MC program, limiting the generalisability of the findings. Further research with larger sample of participants and facilitators is warranted to increase the confirmability of the findings.

Differences in treatment compliance in the MC and MR only groups may have potentially accounted for the significant findings observed, thus limiting the certainty of the results. Disengagement was cited as the main reason for discontinuing the MR program, highlighting difficulties in implementing this program for autistic adults. In addition to improving the motivational value of CBI, future experimental trials evaluating the MC program should control for intervention dosage, enabling better comparison of the effects of facilitator support in improving generalisation outcomes.

The MASC assessment was chosen as an emotion recognition distant generalisation measure in this study, given its demonstrated sensitivity in distinguishing between autistic and non-autistic individuals (Muller et al. 2016). Additionally, the MASC assessed skills in a different context to the MC and MR, enabling assessment of possible transference of skills to real life social emotional contexts (Tang et al. 2019a). While evaluation using the MASC demonstrated positive outcomes, it is ultimately a lab-based assessment, leaving open the question as to its capacity to capture skill generalisation to real life situations. Further evaluation into the external validity of the MASC is warranted. Future research may also seek to incorporate broader measures of social emotional change, such as via observational ratings of social emotional behaviours, or assessment of social emotional aspects of adaptive functioning.

## Conclusion

This paper described the development of a social emotional program for autistic adults. The MC program was developed, incorporating four theoretical perspectives and community feedback underpinning the essential mechanisms for targeting the social emotional understanding of autistic adults. Findings suggest combining the MC program with CBI demonstrated partial acceptability and feasibility as a social emotional program for autistic adults. Participants provided suggestions for improvement, including strategies for individualising social emotional content and increasing the motivational value of the CBI. The MC program combined with a CBI demonstrated preliminary efficacy for improving emotion recognition generalisation outcomes. While these early findings are promising, further research employing an adequately powered larger randomised controlled trial design is recommended to evaluate the effectiveness of the MC program.

**Acknowledgments** The authors acknowledge the financial support of the Cooperative Research Centre for Living with Autism (Autism CRC) [Project Number 3.032RS], established and supported under the Australian Government's Cooperative Research Centres Program. JT was supported by funding from an Australian Postgraduate Award scholarship from the Australian Federal Government and a top-up scholarship from the Autism CRC.

**Author Contributions** All authors contributed to the study conception and design. Data collection and analysis were performed by JT. MF, NC, SB and SG contributed to the interpretation of the data. The first draft of the manuscript was written by JT. MF, NC, SB and SG contributed to the revision of the draft. All authors contributed to and have approved the final manuscript.

### Compliance with Ethical Standards

**Conflict of interest** The authors declare that they have no conflict of interest. SB reports no direct conflict of interest related to this article. SB discloses that he has in the last 5 years acted as an author, consultant or lecturer for Shire, Medice, Roche, Eli Lilly, Prima Psychiatry, GLGroup, System Analytic, Kompetento, Expo Medica, and Prophase. He receives royalties for text books and diagnostic tools from Huber/Hogrefe, Kohlhammer and UTB.

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# Chapter 8 : Discussion and conclusion

CHAPTER EIGHT

# Preface

Chapter 8 synthesises and summarises the research findings, and provides a critical review of the contributions, including limitations and recommendations for future research. Suggestions are also made for reconceptualising interventions that support the social emotional skills of autistic adults.

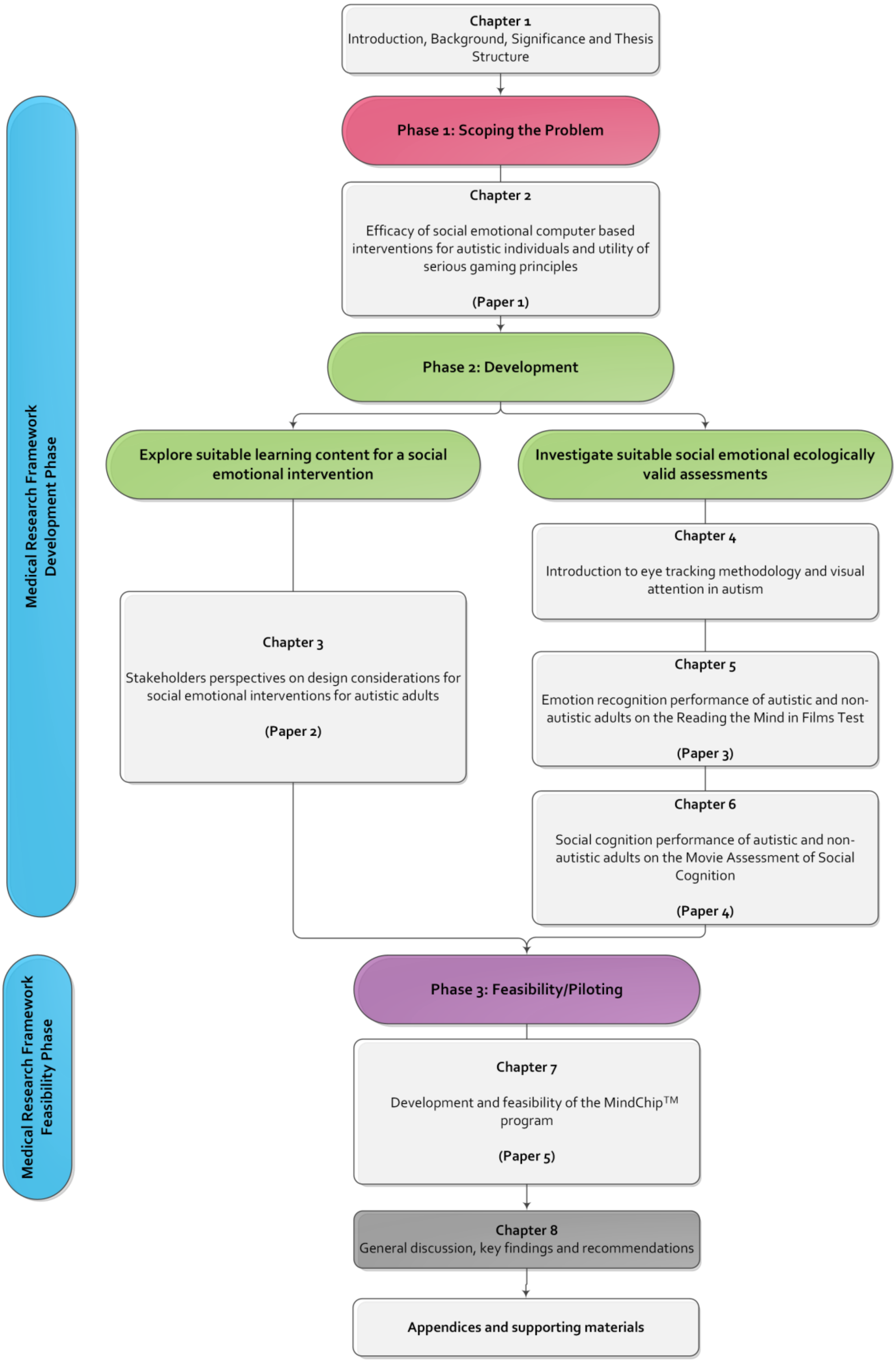


**Figure 8.1 Thesis structure Chapter 8.**

# Overview

Social emotional difficulties are postulated as contributing to the poorer social participation outcomes of autistic adults (1–3). Current interventions aiming to remediate such difficulties mostly take two main approaches: facilitator-mediated and computer-based approaches (4). While these interventions showed promise for autistic individuals, evidence supporting the generalisation of skills to real-world social environments was notably limited. There is a clear need for future research that focuses on developing and evaluating age-appropriate and engaging social emotional learning content for autistic adults. The overall aim of this thesis was to develop a social emotional intervention for autistic adults, specifically for furthering the engagement and generalisation of skills learnt in CBI to naturalistic environments. The MRC for developing complex interventions (5) guided the creation of MindChip™, a social emotional program tested in this thesis. This was discussed in three phases, first for scoping of the problem, and then for development and feasibility testing. The final chapter provides a general discussion of the key findings, implications and recommendations for future research and practice.

# Key findings and implications

## Phase 1: Scoping the problem

Phase 1 of this thesis (see Chapter 2) aimed to review existing evidence and identify the research gaps and active mechanisms driving social emotional efficacy. Chapter 2 first synthesised the intervention applications of existing social emotional CBIs and systematically reviewed their utility in targeting the social emotional skills of autistic individuals. Results gathered indicate that existing CBIs employed a variety of intervention methods for targeting individuals' social emotional skills. Meta-analytic findings in Chapter 2 were the first to examine the differential effect of social emotional CBIs in generalising skills, providing a more comprehensive understanding of their efficacy in transferring the acquired skills to everyday environments. Findings also showed promising evidence for computer-based platforms in improving social emotional skills; however, improvements are mainly limited to close generalisation skills, with a smaller effect observed for distant generalisation (4).

Given that distant generalisation outcomes likely reflect genuine improvements in the transfer of acquired skills to everyday social environments, Chapter 2 further examined the efficacy of CBI and the potential of adopting serious game design principles (6) to enhance the social emotional outcomes for autistic individuals. The meta-analysis is the first to quantify the value of integrating serious game design principles in CBI. It was concluded that implementation was associated with improved social emotional generalisation outcomes to everyday social interactions and transferability to skills not directly targeted in interventions (4); this highlights the importance of considering serious game design for CBI development in autism. Evidence supporting this conclusion was obtained through a novel scoring system underpinned by the serious game design principles outlined by Whyte et al. (6). This enables future research to systematically evaluate the integration of such principles in CBI development for autistic individuals.

In light of the meta-analyses, Chapter 2 further elucidated a number of likely factors possibly accounting for the association between serious game design and improved intervention outcomes. More specifically, the value of such principles in generalising learning to everyday environments may be partly attributable to their emphasis on fostering user engagement (7). Fundamentally, serious games acknowledge that some educational content is inherently uninteresting or challenging, and potentially deters individuals from adequately engaging with the intervention (6). Serious games aim to rectify user disengagement by incorporating educational content into a gaming platform, including gamification and scaffolding features promoting intrinsic and extrinsic motivation (8). Motivation further increases usage time and intervention adherence, in turn, maximising learning outcomes (9). Additionally, the multimodal nature of serious games offers opportunities for contextualised learning across multiple social emotional contexts (4, 6), possibly explaining the association between increased application of serious games principles and improved social emotional gains. For example, narratives in serious games provide opportunities for immersive experiences, thus, facilitating problem-solving skills while managing realistic and complex situations and obstacles (10, 11). Indeed, this further increases opportunities for contextualised learning.

Chapter 2 also revealed consistently high attrition rates across the studies examined. This suggests that existing social emotional CBIs are limited in their ability to capture the attention and interest of autistic individuals (4, 12, 13), likely due to oversimplification or the minimal integration of gamification approaches (14). For example, social emotional CBIs for autistic individuals largely integrate reward systems with traditional therapeutic exercises, with only minimal consideration of the appropriate gamification approaches in intervention design (13–15). While combining simplified approaches with traditional learning exercises has shown some positive results in targeting individuals' social emotional skills, Chapter 2 highlighted that these improvements were limited to close generalisation skills. Results suggested inadequate efficacy for social emotional CBI in promoting generalised learning to real-world environments (4). Findings from Chapter 2 further reinforce the significance of integrating serious game principles in CBIs for autistic individuals. Intervention approaches encouraging the practice of social emotional skills across varying contexts arguably yield more robust gains for autistic adults (16). Consideration of gamification principles is crucial in developing CBIs, both for improving therapeutic effectiveness and ensuring that the interface usability aligns with the specific needs of autistic individuals (17).

# Phase 2: Development

The second phase focused on developing a facilitator-mediated social emotional program called MindChip™. This comprised of two arms exploring key intervention features and informing a suitable measurement framework for evaluating social emotional interventions for autistic adults.

## *Intervention features*

Chapter 3 explored the perspectives of key stakeholders, including autistic youth, health professionals and educators in autism—regarding suitable features for a social emotional intervention. Involving stakeholders in the development of CBI is emerging as best practice (18–20), as the integration of diverse perspectives from various stakeholders and disciplines actively promotes positive outcomes (21). Both autistic youth and professionals provided suggestions relating to the motivational and generalised learning aspects of such interventions (22), therefore, addressing the two research gaps reported in currently available social emotional CBIs for autistic individuals (4, 23, 24). Considering and giving weight to the perspectives of all relevant stakeholders ultimately contributes to the meaningfulness and acceptability of the resulting intervention (21). Findings in Chapter 3 highlighted important recommendations for developing age-appropriate social emotional learning content for autistic adults, which are imperative given the paucity of existing interventions targeting autistic adults (25, 26).

The focus group study (Chapter 3) highlighted the preference of both autistic youth and professionals for including realistic scenarios within social emotional interventions, as these provided a tangible connection with real-life situations and expectations (22). Professionals also suggested that the goals of CBI should reflect naturalistic social situations, with particular focus on developing skills related to understanding and responding to emotions. Currently available social emotional interventions targeting autistic adults largely focus on learning goals directly associated with recognising emotion; this includes correctly identifying emotions from static pictures or dynamic videos (13, 15, 27), with minimal consideration of body gestures, voice and contextual cues (28–30). Previous research suggests that some autistic adults may have subtle difficulties with social emotional skills (31, 32), with increasing difficulties particularly during unstructured social environments (33–35), for tasks requiring contextual sensitivity (36), and with attributes representing the social demands of real-life environments (37). Given these difficulties, it has been suggested that the processing of social emotional information requires more effort in autistic individuals, taxing their ability to cope in everyday social situations (32, 35). Collectively, the findings suggest that social emotional interventions for autistic adults could be further enhanced by including content representing real-life expectations, including strategies for understanding the contextual meaning of social emotional situations.

Findings from Chapter 3 also highlighted the importance of teaching autistic youth problem-solving strategies that support their functioning during everyday social emotional situations (22). It must be acknowledged that the spectrum of social emotional functioning in autism is wide, with some individuals demonstrating minor or total absence of impairments during social emotional tasks (38–42), and others showing improvements in social emotional skills in adulthood, despite significant difficulties as children (42). The apparent heterogeneity in the social emotional skills between adults suggests a need to reframe the social emotional *deficit* paradigm in autism to one of social emotional neurodiverse *differences* (43). Traditionally, social emotional interventions are framed under the *deficit* paradigm, judging autistic behaviours as inappropriate in social emotional interactions and, thus, emphasising the teaching of non-autistic norms or promoting camouflaging of autistic characteristics in social situations (44). While the benefits of camouflaging may include assimilation and facilitating connections in this context, this approach in the long term has the potential to negatively affect the mental health of autistic individuals (44, 45).

## *Assessment evaluation*

The second arm of Phase 2 aimed to determine suitable assessments that utilise naturalistic contexts for evaluating the distant generalisation outcomes of social emotional interventions. Chapters 5 and 6 added to the knowledge of ecologically valid assessments that can differentiate the social emotional functioning of autistic and non-autistic adults. The studies further provided insight on the strategies autistic adults employ by investigating their gaze patterns when processing social emotional information.

The case control study in Chapter 5 compared the social emotional performance of autistic and non-autistic adults using the RMFT. The conclusion that no significant group differences in emotion recognition accuracy were found suggests that this assessment might not be sufficiently complex to elicit differences in social emotional skills between groups (46). Chapter 5 findings further highlighted the notion that social emotional difficulties may not be universally present in autistic individuals (41). The results of the subsequent case control study (see Chapter 6) revealed contrasting results reported in Chapter 5, as the autistic adults demonstrated increased difficulties in social emotional skills (according to MASC) compared to the non-autistic group. Collectively, these findings conclude that MASC was a more appropriate assessment tool for detecting social emotional differences and is, therefore, likely more receptive to changes in response to a social emotional intervention for autistic adults.

Incongruities in the findings between the performance of autistic adults on the RMFT and MASC and the heterogeneous findings reported in recent social emotional literature question the extent to which these individuals experience social emotional difficulties (41). It is likely that differences in the specific measurement properties of both tests affected their capacity to adequately capture the subtleties of autistic adults. While both the RMFT and MASC utilised ecologically valid stimuli, they differ in terms of presentation—a factor previously noted as contributing to the heterogeneity of findings in the current literature (41, 47). Specifically, MASC is underpinned by an overall narrative linking segments, with successful performance dependent on inferring and integrating contextual information from previous social scenes (48, 49). Tasks requiring context sensitivity have been reported as more demanding for autistic individuals (36, 50, 51). Additionally, the RMFT explicitly cues participants towards the target character within the stimuli, possibly alleviating the cognitive demands associated with social emotional processing (41, 52, 53). Both context-driven narratives and spontaneous processing are regarded as qualities representing real-life social interactions (36, 37). Overall, these findings and those presented in Chapters 5 and 6 suggest that compared to the RMFT, MASC more accurately depicts everyday social emotional situations and, therefore, provides a more appropriate outcome measure for assessing skill generalisation in evaluations of social emotional interventions.

Further analysis of eye-tracking measurements in Chapters 5 and 6 revealed that autistic adults employ equivalent visual search strategies in the RMFT and MASC. In both studies, autistic adults demonstrated comparatively increased fixation duration to non-social regions and less on characters' faces in the social emotional scenes. Interestingly, despite the autistic group demonstrating similar visual search strategies, these findings were observed in combination with comparable outcomes and differences in social emotional performance on the RMFT and MASC, respectively. While eye tracking provides helpful insight on visual and cognitive processing (54), the results reveal dissociation between visual mechanisms and social emotional performance. This perhaps suggests that eye-tracking methods may not be sufficient in providing a full explanation of the social emotional performance of autistic individuals.

Discrepant findings between eye-tracking and social emotional performance measures may indicate that autistic adults employ a variety of strategies in social emotional processing. Specifically, Chapter 6 found that autistic adults may require more effortful cognitive strategies in social emotional tasks, while in non-autistic individuals these processes are more spontaneous—thus, corroborating findings from previous studies (55–57). Recent literature reported autistic adults, especially those with higher verbal functioning—adopt alternative strategies when problem-solving social emotional tasks (58–60). For example, as demonstrated in Chapter 6, autistic adults exhibited non-autistic gaze patterns to characters' facial regions, possibly indicating that they may have utilised previously learnt adaptive social behaviour (59). In some cases, compensatory strategies may be facilitating autistic adults' social emotional performance (32, 56, 61), contradicting other studies that reported persistent social emotional difficulties, especially during advanced social emotional tasks (56, 62).

# Phase 3: Intervention development and feasibility study

Findings from Chapters 2 to 6 provided quantitative evidence for (1) implementing serious game design for improving intervention efficacy, (2) appropriate social emotional learning content for autistic adults, and (3) a suitable distant generalisation assessment for evaluating social emotional interventions. Leveraging on the findings in Phases 1 and 2, the final phase (see Chapter 7) aimed to develop and evaluate the feasibility of a novel facilitator-mediated social emotional program for autistic adults, known as MindChip™. Given that a theory-driven approach is fundamental in intervention development (63), Chapter 7 further aimed to explore suitable theoretical underpinnings for delivering the program.

Chapter 7 outlined the theoretical framework of the MindChip™ program, considering both the personal and social constructs enabling the social emotional understanding of autistic adults (Figure 8.2). From a *personal* perspective, the program integrated the constructs from self-efficacy and self-management theories (64, 65). Supporting self-efficacy is conceived as underpinning performance mastery and successful goal attainment (64, 66), and in the context of MindChip™, this was key in empowering autistic individuals to develop the confidence needed to effectively manage challenging social emotional situations. Previous research has shown that increased self-efficacy is closely associated with learning motivation, a recognised antecedent for generalising learning (67, 68).

Within the self-management approach, action planning supports an individual's self-efficacy in determining the necessary steps to achieve a desired goal (69, 70). In the context of the MindChip™ program, action planning supported the autistic adults in predetermining the steps for translating new social emotional strategies to their everyday social environments. Supporting individuals in autonomously creating personally meaningful action plans that improve their everyday outcomes is essential in the action-planning process (71). Highlighting to individuals that their efforts in action planning will result in rewards promotes generalised learning (67). While findings from the feasibility study (Chapter 7) did not reveal significant group differences in self-efficacy scores, participants receiving the MindChip™ program provided qualitative data indicating improvements in social emotional self-efficacy, including improved confidence in understanding and problem-solving social emotional situations in their everyday lives. These findings provide some promising evidence for the MindChip$^{TM}$ program in targeting the social emotional skills of autistic adults.

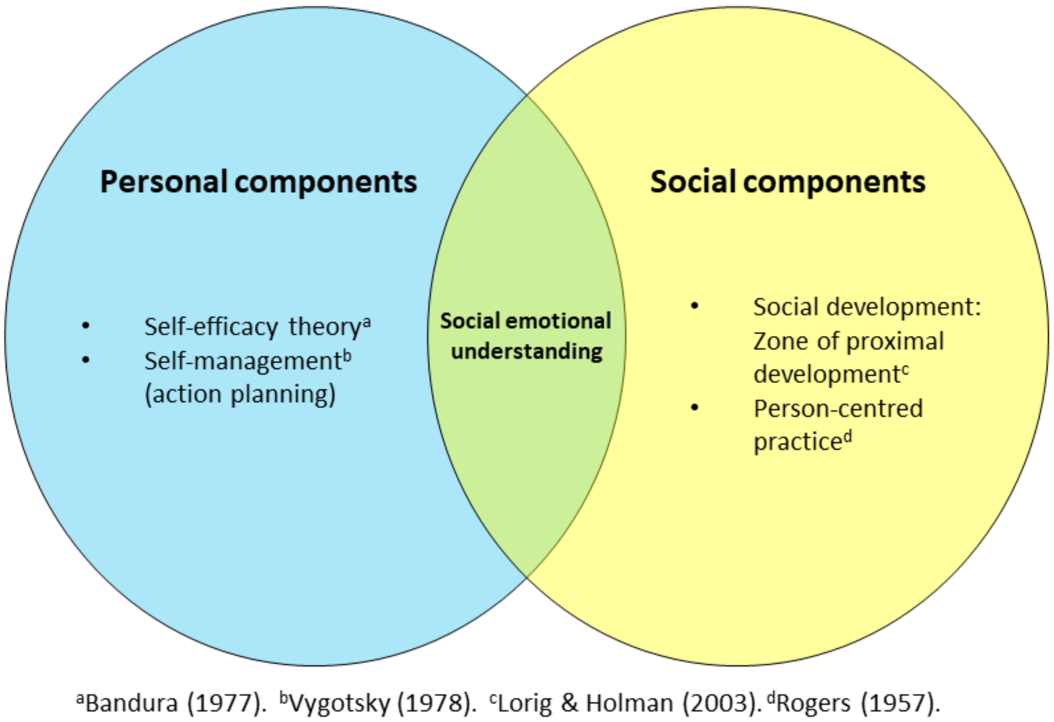


**Figure 8.2. Theoretical framework underpinning the MindChip$^{TM}$ program, an integration of personal and social components for targeting social emotional understanding of autistic adults.**

From a *social* theoretical perspective, the MindChip$^{TM}$ program acknowledged that an individual's capacity for learning is enhanced through social support (65). Embedding facilitator support within MindChip$^{TM}$ enabled scaffolding of complex social emotional skills, increasing knowledge and empowering individual confidence in managing everyday social environments (72–75). Guided by the person-centred approach, the MindChip$^{TM}$ facilitator adopted an individualised approach, prioritising the goals that users identify (76, 77). Tailoring interventions to one's needs is likely crucial, given the heterogeneity of autism and the widely reported variability in responses of social emotional interventions (78–80). Traditionally, these approaches in autism have adopted direct instructional paradigms, with an 'expert' providing explicit prompting based on the incorrect or correct responses (81)—a paradigm mirrored in existing social emotional CBIs for autistic adults (13, 27). While previous research has demonstrated the efficacy of this approach in promoting initial learning acquisition, engagement and maintenance of learnt skills deteriorates over time (82). Evidence suggests an individualised approach generates greater intervention gains, including more substantial improvements in mental health and more sustained maintenance of skills following intervention (83). Feedback obtained from participants engaged in the MindChip$^{TM}$ program (Chapter 7) endorsed its individualised approach, linking this with promoting engagement and supporting learning. Taken together, the findings from Chapter 7 demonstrate that individualising social emotional content and facilitator mediation show considerable promise in improving the efficacy of social emotional CBIs for autistic adults.

Overall, Chapter 7 highlighted that the implementation of social emotional CBI can be further enhanced through employing individualised facilitated approaches. This was achieved by adopting a theory-driven approach, hence, providing a detailed outline of the theoretical foundations for a facilitator-mediated social emotional program called MindChip$^{TM}$. The feasibility study further provides quantitative and qualitative preliminary evidence for combining CBIs with MindChip$^{TM}$, with greater gains in distant generalisation skills observed for autistic adults in this group compared to the CBI only group. The findings also indicate genuine gains in transferring social emotional skills to everyday social environments. Conversely, existing CBIs largely rely on didactical teaching to develop social emotional skills, providing opportunities for autistic individuals to learn difficult concepts in a safe learning environment (13, 84). However, didactically teaching social emotional skills alone is likely insufficient in promoting their application to naturalistic social situations, and this likely limits the efficacy of CBI in improving generalised learning (16, 23). As such, facilitator-mediated approaches can enhance social emotional CBI and provide social reinforcements and opportunities for practising skills in naturalistic contexts (85).

# Limitations

The next section of this chapter outlines the methodological limitations of this thesis project, including recommendations for future research. The limitations delineate methodological considerations relating to research design, sample size and outcome measures.

# Research design

The MindChip$^{TM}$ program design was based on the input from stakeholders, using focus group methodology and pilot testing. These approaches can be advantageous in gathering recommendations for appropriate intervention components and identifying possible acceptability and feasibility limitations prior to evaluating the intervention in a larger experimental trial (86). While these approaches are helpful in eliciting ideas, they are considered consultative and researcher driven and, therefore, insufficient in providing opportunities for authentic and meaningful stakeholder partnerships when developing interventions (14, 87). Inclusive research design is considered best practice in intervention development (88), providing an empowering experience for autistic individuals and experts to actively contribute at all stages of the process (19). Social emotional CBI utilising inclusive research design approaches have demonstrated positive results in enhancing user engagement, intervention adherence and relevancy (21). In this study, some inclusive research designs strategies were implemented during the development of MindChip$^{TM}$, including involving autistic adults to review the program manual and providing feedback on the appropriateness of its aims and activities (Chapter 7). Future refinement could consider implementing best practice inclusive research design principles, enhancing the appropriateness and usability of the program.

The content for MindChip$^{TM}$ was developed as an adjunct to the existing social emotional CBI known as Mind Reading, designed to target autistic adults (13). The software previously demonstrated good outcomes in improving the social emotional skills of autistic adults, with feedback suggesting good engagement in the gaming activities (89, 90). At the time of the present research, Mind Reading was the only commercially available social emotional CBI for autistic adults and, therefore, the most appropriate option. One of the greatest challenges in conducting this research project was controlling participants' adherence when completing the software. Only 12% of respondents (*n* = 25) in both intervention arms completed the 10 hours' recommended dosage of Mind Reading software, citing technical difficulties, disengagement and competing commitments as the main reasons for their poor adherence. The group receiving both MindChip$^{TM}$ and Mind Reading programs demonstrated higher adherence (>80%) and increased use of the latter software. Discrepancies in intervention dosage between groups would have favoured the MindChip$^{TM}$ and Mind Reading group, possibly limiting the confirmability of the results.

This research study employed a two-arm, pilot randomised controlled trial aiming to determine the feasibility and preliminary effectiveness of implementing MindChip$^{TM}$ with an existing social emotional CBI. An active control group design was used, permitting comparison between the group receiving both the MindChip$^{TM}$ program and CBI and the CBI only group. While the active control design employed in Chapter 7 enabled estimation of the relative effectiveness of MindChip$^{TM}$ and CBI only (91), the effect of the program alone could not be determined given there was no inactive control group or a MindChip$^{TM}$ program only arm (91).

It is important to note that only one facilitator delivered the MindChip$^{TM}$ program in this study. Although this possibly limits the generalisability of the findings, it also likely enhances the program's transferability to other autistic adults given its basis to address individualised social emotional goals and skills. Given that MindChip$^{TM}$ was delivered by a single facilitator, the potential replicability of the program with several facilitators in future evaluation studies and subsequently for other MindChip$^{TM}$ service providers remains unclear (92).

# Sample

Recruitment and sampling in the study was restricted to Western Australia, due to practical restrictions in administering the measurements utilised for analysis. A variety of recruitment methods were employed with the goal of enhancing the representation of autistic adults, health professionals and educators. This included contacting families who previously showed interest to participate in research, advertising through autism organisations throughout Western Australia, engaging in social media platforms and using snowball sampling. Despite the variability in recruitment methods, the sample size in this study is considered small, with a total of 155 participants recruited across the four studies in this thesis (Chapter 3, *n* = 22; Chapter 5, *n* = 48; Chapter 6, *n* = 60; Chapter 7, *n* = 25). Additionally, autistic adults were homogenously sampled due to the research criteria excluding individuals scoring below the IQ of 70. Taken together, the small sample size and demographic restrictions employed in this research may limit both the statistical power of the results and their generalisability to the wider autistic population.

## Outcome measures

It should be acknowledged that the two ecologically valid assessments reported in Chapters 5 and 6 mainly evaluated receptive social emotional skills, minimally considering skills relating to selecting appropriate behavioural responses in social environments. The latter requires more sophisticated integration of social emotional skills, a component that is reportedly more challenging for autistic individuals (93, 94). Additionally, the assessments were administered in a controlled laboratory-based setting, possibly reducing the social emotional demands typically present in real-life environments. In turn, this limits the ecological validity of these measures as assessments of generalised social skills.

Given the limited range of currently available measures assessing the social emotional self-efficacy of autistic adults, the ERSE was developed specifically for the feasibility study in Chapter 7 to gauge the preliminary effectiveness of MindChip$^{TM}$ in improving self-efficacy. Results revealed no significant group differences in ERSE outcomes, suggesting that this assessment may not be adequately sensitive in detecting changes in social emotional self-efficacy. The non-significant findings are likely confounded, at least in part, by small sample sizes. Given the multidimensional construct of self-efficacy in social emotional interactions (95, 96), further psychometric testing of the tool was considered beyond the scope of the thesis.

# Recommendations

The findings in this thesis highlight approaches for further development and evaluation of social emotional CBIs for autistic adults. They also emphasise the importance of improving engagement and focusing on generalising learning outcomes to everyday social environments. The remainder of Chapter 8 outlines recommendations for future development of the MindChip$^{TM}$ program, clinical practice and future research.

## Recommendations for MindChip$^{TM}$

Traditionally, social emotional interventions for autistic individuals have been underpinned by a paradigm focused on remediating deficits, with minimal consideration of autistic strengths in social emotional processing (32, 97). Given increasing awareness of the value of neurodiverse approaches to improve the outcomes of autistic adults (98), there is a clear need for interventions that adopt individualised approaches when targeting social emotional skills. While the sample group regarded MindChip$^{TM}$ as useful and acceptable, greater tailoring of intervention content to individual needs would likely enhance efficacy of the program. This could be done through strategies that include comprehensive initial assessment and further profile participants' strengths and difficulties in social emotional skills. This information would support modification of the program based on an autistic adult's skills and identified goals, as well as inform a determination of MindChip$^{TM}$'s suitability for individual needs.

Informed by participant recommendations presented in Chapter 7, including more advanced social emotional content within the MindChip$^{TM}$ program would extend the target population to a greater number of autistic adults. Respondents indicated that the content focusing on understanding emotional cues covered during the initial few weeks might have been too simplistic. This is consistent with previous studies reporting intact performance of autistic adults in recognising facial expressions (99), body language (100) and vocal intonation (101). Specifically, advanced modules of the MindChip$^{TM}$ program could focus on developing a more in-depth understanding of contextual cues and strategies for managing the spontaneous nature of everyday social emotional situations (33, 36). This includes exploration of social emotional strengths and personalised social emotional strategies (32).

Importantly, efficacy testing the implementation of MindChip$^{TM}$ combined with CBI in this thesis is preliminary, warranting further development and re-evaluation of the program. Improvement can be further enhanced by adopting inclusive research design methods, with development undertaken in partnership with researchers and end users (14). Co-production practices necessitate engagement with autistic individuals and relevant professionals in a series of development workshops involving iterative reviewing and refining of intervention content and resources (86, 102). Despite the benefits of employing inclusive research designs, challenges commonly occur in relation to managing divergent perspectives in interdisciplinary co-production teams (88). A future MindChip$^{TM}$ co-production team could mitigate some of these challenges by providing several feedback options and acknowledging the distinct expertise of stakeholder groups (14, 87). Employing inclusive research methodology in the future development of MindChip$^{TM}$ has the potential to further maximise its therapeutic acceptability and effectiveness for autistic adults.

Given that the Mind Reading software demonstrated poor acceptability in the study, future research could possibly re-evaluate the efficacy of MindChip$^{TM}$ as a standalone social emotional intervention for autistic adults. Alternatively, a new social emotional CBI could be developed for this group and integrated into MindChip$^{TM}$. That said, CBI development can be resource intensive and requires expertise in varying disciplines, including human–computer interaction, education and autistic adults themselves. Future multidisciplinary collaboration is recommended when developing social emotional CBI for autistic adults. Engagement with a stakeholder organisation is also essential for facilitating the recruitment outreach and implementation of the program with multiple facilitators. This strategy would increase the generalisability of the research findings to the wider autistic population and enable evaluation of MindChip$^{TM}$'s potential fit within the larger organisational context.

## Recommendations for clinical practice

Although the results in this thesis are preliminary, the findings provide some useful implications for clinical practice. This section discusses in greater depth the recommended approaches for targeting the social emotional skills of autistic adults, including individualisation, contextual understanding, person centredness and telehealth modalities.

### *Individualisation*

ASD is widely recognised as a heterogeneous condition with varying functioning profiles (79). As indicated in Chapter 7, utilising an inflexible approach may limit the therapeutic effectiveness of intervention, thus, necessitating more personalised methodologies based on the specific needs of autistic individuals (103). Enquiring and acknowledging the strengths of each person is an important consideration for individualising interventions (32). Conducting an initial assessment of autistic adults' social emotional understanding and prioritised areas for further development is recommended for customising interventions. Periodic reviews with autistic adults are equally crucial in tailoring and adapting interventions to one's needs, strengths and priorities, and, therefore, enable a more holistic approach for addressing social emotional skills. The process of setting individualised social emotional goals could be closely coupled with an outcome measurement, quantifying the individual's perception of their improvement or progress towards their goals. This further provides an ecologically valid and personally relevant outcome measure for the MindChip$^{TM}$ program. Additionally, exploring individualised problem-solving strategies rather than focusing on autism-related deficits has been posited as a more productive and beneficial approach for autistic adults, as this empowers them to discover their social emotional strengths and potentially facilitates positive mental health outcomes. This includes discussing strategies enabling non-autistic individuals to understand autistic social emotional interactions, rather than promoting blanket acceptance of wider social norms.

## *Contextual understanding*

As highlighted in the focus group study (see Chapter 3), intervention content emphasising contextual understanding is essential for maximising the social emotional skills of autistic adults in realistic social environments. Interventions focusing on contextual understanding include discussions on the variability of social environments, multimodal processing of environmental cues, situational expectations and individuals' past experience (104). Focusing on developing contextual understanding in CBI adds another dimension of complexity for autistic adults, particularly given their noted difficulties with these concepts (36). Contextual understanding in social emotional interventions can be addressed by presenting and discussing multiple social scenarios, in turn, highlighting that expected behaviour can vary depending on the context. Initial discussion of contextual understanding can include evaluating the effect of more noticeable contextual clues, including others' actions or objects in the surrounding environment. More advanced contextual understanding could include content relating to hidden contextual clues, such as unwritten social norms and cultural or personal factors. It is imperative to relate each discussion with the relevant experiences of autistic adults to facilitate the engagement and generalisation of learnt strategies to everyday environments. It is postulated that shifting the focus of social emotional interventions from acquiring skills to developing contextual understanding has the potential to promote the generalisation of learning to social settings.

## *Person centredness*

Person-centred approaches emphasising partnering *with* rather than making decisions *for* an individual are critical for facilitating learning (76, 77). Application in social emotional interventions requires facilitators to step away from the leading role and allow exchanges of experience and ideas between themselves and autistic adults (77). This dyadic partnership can be further enhanced by discussing problem-solving strategies and utilising the unique strengths of autistic adults and environmental adaptations (32, 105). Adopting person-centred approaches to social emotional interventions may provide an avenue for autistic adults to reframe their differences in social emotional interactions, resulting from contextual or relational factors rather than exclusively from their impairments (43, 106). This approach can further facilitate the discovery of autistic strengths in social emotional processing (32).

## *Telehealth modalities*

Telehealth interventions are beneficial in increasing the accessibility of services and providing a cost-effective intervention option for individuals (107). Previous autism research reports good feasibility and preliminary effectiveness of telehealth modalities in educating parents (108), diagnostic assessment (109), early intervention (110) and communication training (111). Collectively, this research indicates that telehealth is a potentially useful modality for delivering social emotional interventions to autistic individuals. As highlighted in the pilot study (Chapter 7), autistic adults agreed that the teleconferencing platform utilised in MindChip™ was feasible to implement, provided an increase in scheduling flexibility and resolved difficulties associated with travel constraints. While telehealth could be a promising alternative to face-to-face intervention, technological barriers such as limited internet availability and reliability may affect individual experiences, especially in remote and rural Australia (112). Future social emotional interventions could consider utilising telehealth modalities by providing options for autistic adults to connect through audio and video conferencing facilities, provided that this modality is deemed appropriate for their individual needs. Some considerations for determining telehealth suitability include availability of appropriate technology and support, as well as the participation capacity of users' support needs, including considering their physical, mental, social and/or cognitive support needs. Further guidelines for establishing a telehealth intervention in Australia are outlined in the New South Wales Agency for Clinical Innovation document (113).

# Recommendations for future research

The findings of the systematic review (see Chapter 2) and limitations outlined in this chapter highlight the paucity of standardised measures for evaluating the generalisation of autistic adults' social emotional skills to real-life scenarios, contributing to the heterogeneous outcome measures employed. While MASC previously reported good psychometric properties (49) and demonstrated sensitivity in distinguishing autistic and non-autistic social emotional differences (Chapter 7), larger standardisation of the tool that provides a norm-referenced clinical cut-off score is yet to be conducted. Future research could seek to develop social emotional standardised assessments for evaluating distant generalisation outcomes. Developing standardised assessments and ensuring consistent use of outcome measures, can expedite research replicability and comparability, facilitating the determination of effective interventions for autistic adults (114).

# Summary and conclusions

This thesis described the three-phased development process of a facilitator-mediated social emotional intervention delivered in combination with a CBI, known as MindChip$^{TM}$. These efforts provide important implications for targeting and evaluating the social emotional skills of autistic adults. The first phase, 'scoping the problem', justified the development of new research that explores active mechanisms for improving the distant generalisation outcomes of social emotional interventions. Findings from this thesis provide quantitative evidence for utilising serious gaming principles (6) as a useful framework to understand the key components of improving the engagement and generalised learning outcomes of autistic adults.

In Phase 2, stakeholders' perspectives revealed that social emotional content that focuses on realistic scenarios, contextual understanding, exploration of social emotional strengths and personalised strategies were considered both as age-appropriate and relevant topics for autistic youth. Findings of the studies examining ecologically valid assessments revealed that

MASC compared to the RMFT was a more suitable assessment for measuring social emotional distant generalisation outcomes of autistic adults. Further, assessment properties encompassing context-driven narratives and eliciting spontaneous processing likely provide a more sensitive social emotional measure for assessing distant generalisation outcomes. Eye-tracking results also suggested that autistic adults demonstrated greater fixation to non-social regions. The findings were observed in conjunction with both comparable and diverse social emotional performance between autistic and non-autistic adults, suggesting that the former may employ a variety of strategies when processing social information. Collectively, these findings further indicate heterogeneity of the autistic social emotional profile, necessitating the importance for future research to reconceptualise to a social emotional neurodiverse *differences* model (32, 43).

Finally, the findings indicated good acceptability and satisfaction of the MindChip™ program, providing preliminary support for the efficacy of individualised and self-efficacious approaches in targeting the unique social emotional needs of autistic adults. Preliminary efficacy testing of the program combined with CBI shows promising results, with significant improvements observed for social emotional distant generalisation outcomes; this is indicative of better translation of skills to real-world social environments. However, low adherence observed in the CBI component of MindChip™ suggests there are issues with the engagement and motivational aspects of this CBI approach. Future research is recommended to explore more efficacious interventions when integrating serious gaming principles into CBI targeting autistic adults.

In summary, the findings address noted research gaps in the literature. Further explored are strategies for improving autistic adults' engagement in computer-based social emotional interventions and promotion of the generalisation of learnt skills. Ultimately, the success of interventions targeting the latter in real-world interactions is a marker of their true efficacy. Given the poorer functional outcomes of autistic individuals in adulthood—including increased social isolation (115), lower quality of life (116) and employment outcomes (117)—there is a clear need for effective interventions that improve both the social and occupational functioning outcomes of autistic individuals. This was highlighted in a testimony from one MindChip$^{TM}$ participant, who expressed the following:

> I had to apply for an internship where I had to recognise faces and complete math-based games on the computer … I just barely made it into the top 20% of people who have done the games … so thank you.

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# Appendices

## Appendix A: Systematic review database search strategies

PsychInfo (Ovid)

Updated search on 17th of December 2018: 1317 articles

1. Exp autism spectrum disorders/ or exp autistic thinking
2. Autis*
3. Asperger*
4. ASD
5. ‘pervasive development disorder*’
6. PDD
7. 1 OR 2 OR 3 OR 4 OR 5 OR 6
8. Exp computers/ or exp computer games/ or exp computer assisted design/ or exp computer assisted therapy/ or exp computer software
9. Exp computer training/
10. Exp assistive technology/
11. Exp games/ or exp simulation games/
12. Exp computer assisted instruction
13. Computer*
14. Software*
15. Technolog*
16. ‘computer based’
17. ‘computer assisted’
18. ‘computer game*’
19. ‘video game*’
20. ‘serious game*’
21. ‘simulation game*’
22. ‘online game*’
23. ‘game based learning’
24. 8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14 OR 15 OR 16 OR 17 OR 18 OR 19 OR 20 OR 21 OR 22 OR 23
25. exp social behaviour/ or exp reciprocity/ or exp social cognition/ or exp social interaction/ or exp social perception/ or exp social skills/
26. exp social skills training/
27. exp emotions/ or exp emotion recognition/ or exp expressed emotion/
28. exp empathy
29. exp face perception/ or exp facial expressions
30. soci*
31. ‘social conversation’

32. ‘social interaction’
33. ‘emotion*’
34. ‘face*’
35. ‘facial*’
36. feeling*
37. ‘expression*’
38. ‘turn taking’
39. ‘eye contact’
40. ‘joint attention’
41. ‘empath*’
42. ‘theory of mind’
43. 25 OR 26 OR 27 OR 28 OR 29 OR 30 OR 31 OR 32 OR 33 OR 34 OR 35 OR 36 OR 37 OR 38 OR 39 OR 40 OR 41 OR 42
44. 7 AND 24 AND 43

ERIC (Proquest)

Updated search on 17th of December 2018: 684 articles

(Autis* OR Asperger* OR ASD* OR ‘Pervasive Development Disorder*’ OR PDD) AND (Computer* OR software* OR technolog* OR ‘computer based’ OR ‘computer assisted’ OR ‘computer game*’ OR ‘video game*’ OR ‘serious game*’ OR ‘simulation game*’ OR ‘online game*’ OR ‘game based learning’) AND (Soci* OR ‘social conversation’ OR ‘social interaction’ OR ‘emotion*’ OR ‘face*’ OR ‘facial*’ OR feeling* OR ‘expression*’ OR ‘turn taking’ OR ‘eye contact’ OR ‘joint attention’ OR ‘empath*’ OR ‘theory of mind’)

Medline (Ovid)

Updated search on 17th of December 2018: 1269 articles

1. Exp Child Development Disorders, Pervasive/
2. Autis*
3. Asperger*
4. ASD*
5. ‘Pervasive Development Disorder*’
6. PDD
7. 1 OR 2 OR 3 OR 4 OR 5 OR 6
8. Exp computers/ or exp software/ or exp video games
9. Exp technology
10. Computer*
11. software*
12. technolog*
13. ‘computer based’
14. ‘computer assisted’
15. ‘computer game*’
16. ‘video game*’

17. ‘serious game*’
18. ‘simulation game*’
19. ‘online game*’
20. ‘game based learning’
21. 8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14 OR 15 OR 16 OR 17 OR 18 OR 19 OR 20
22. Exp social behaviour/ or exp social skills/
23. Exp social perception/
24. Exp emotions/
25. Exp facial expression/
26. Exp ‘theory of mind’/
27. Exp empathy/
28. Soci*
29. ‘social conversation’
30. ‘social interaction’
31. ‘emotion*’
32. ‘face*’
33. ‘facial*’
34. feeling*
35. ‘expression*’
36. ‘turn taking’
37. ‘eye contact’
38. ‘joint attention’
39. ‘empath*’
40. ‘theory of mind’
41. 22 OR 23 OR 24 OR 25 OR 26 OR 27 OR 28 OR 29 OR 30 OR 31 OR 32 OR 33 OR 34 OR 35 OR 36 OR 37 OR 38 OR 39 OR 40
42. 7 AND 21 AND 41

CINAHL Plus (EBSCOhost)

Updated search on 17th of December 2018: 924 articles

1. (MH ‘Child Development Disorders, Pervasive+’)
2. TI Autis* OR AB Autis*
3. TI Asperger* OR AB Asperger*
4. TI ASD* OR AB ASD*
5. TI ‘Pervasive Development Disorder*’ OR AB ‘Pervasive Development Disorder*’
6. TI PDD OR AB PDD
7. S1 OR S2 OR S3 OR S4 OR S5 OR S6
8. (MH ‘Computers and Computerization+’) OR (MH ‘Therapy, Computer Assisted+’)
9. (MH ‘Technology+’)
10. (MH ‘Games’) OR (MH ‘Video Games’)
11. TI Computer* OR AB Computer*

12. TI software* OR AB software*
13. TI technolog* OR AB technolog*
14. TI ‘computer based’ OR AB ‘computer based’
15. TI ‘computer assisted’ OR AB ‘computer assisted’
16. TI ‘computer game*’ OR AB ‘computer game*’
17. TI ‘video game*’ OR AB ‘video game*’
18. TI ‘serious game*’ OR AB ‘serious game*’
19. TI ‘simulation game*’ OR AB ‘simulation game*’
20. TI ‘online game*’ OR AB ‘online game*’
21. TI ‘game based learning’ OR AB ‘game based learning’
22. S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21
23. (MH ‘Social Behavior+’)
24. (MH ‘Social Skills’) OR (MH ‘Social Skills Training’)
25. (MH ‘Emotions+’)
26. (MH ‘Facial Expression’) OR (MH ‘Nonverbal Communication+’)
27. (MH ‘Theory of Mind’)
28. (MH ‘Empathy’)
29. TI ‘social conversation’ OR AB ‘social conversation’
30. TI ‘social interaction’ OR AB ‘social interaction’
31. TI ‘emotion*’ OR AB ‘emotion*’
32. TI ‘face*’ OR AB ‘face*’
33. TI ‘facial*’ OR AB ‘facial*’
34. TI feeling* OR AB feeling*
35. TI ‘expression*’ OR AB ‘expression*’
36. TI ‘turn taking’ OR AB ‘turn taking’
37. TI ‘eye contact’ OR AB ‘eye contact’
38. TI ‘joint attention’ OR AB ‘joint attention’
39. TI ‘empath*’ OR AB ‘empath*’
40. TI ‘theory of mind’ OR AB ‘theory of mind’
41. S23 to S40

Embase

Updated search on 17th of December 2018: 2340 articles

1. Exp autism/ or exp Asperger syndrome/ or exp ‘pervasive development disorder not otherwise specified’/
2. Autis*
3. Asperger*
4. ASD
5. ‘pervasive development disorder*’
6. PDD
7. 1 OR 2 OR 3 OR 4 OR 5 OR 6
8. Exp computer/
9. Exp computer assisted therapy/

10. Exp technology/ or exp educational technology/
11. Exp software/
12. Computer*
13. Software*
14. Technolog*
15. ‘computer based’
16. ‘computer assisted’
17. ‘computer game*’
18. ‘video game*’
19. ‘serious game*’
20. ‘simulation game*’
21. ‘online game*’
22. ‘game based learning’
23. 8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14 OR 15 OR 16 OR 17 OR 18 OR 19 OR 20 OR 21 OR 22
24. Exp social interaction/ or exp social cognition/
25. Exp social behaviour/
26. Exp emotion/
27. Exp facial expression/
28. Exp empathy/
29. Exp ‘theory of mind’/
30. Soci*
31. ‘social conversation’
32. ‘social interaction’
33. Emotion*
34. Face*
35. Facial*
36. Feeling*
37. Expression*
38. ‘turn taking’
39. ‘eye contact’
40. ‘joint attention’
41. Empath*
42. ‘theory of mind’
43. 24 OR 25 OR 26 OR 27 OR 28 OR 29 OR 30 OR 31 OR 32 OR 33 OR 34 OR 35 OR 36 OR 37 OR 38 OR 39 OR 40 OR 41 OR 42 OR 42
44. 7 AND 23 AND 43

PudMed

Updated search on 17th of December 2018: 582 articles

(((Autis*[Title/Abstract] OR Asperger*[Title/Abstract] OR ASD*[Title/Abstract] OR ‘Pervasive Development Disorder*’[Title/Abstract] OR PDD[Title/Abstract])) AND (Computer*[Title/Abstract] OR software*[Title/Abstract] OR technolog*[Title/Abstract] OR ‘computer based’[Title/Abstract] OR ‘computer assisted’[Title/Abstract] OR ‘computer game*’[Title/Abstract] OR ‘video game*’[Title/Abstract] OR ‘serious game*’[Title/Abstract] OR ‘simulation game*’[Title/Abstract] OR ‘online game*’[Title/Abstract] OR ‘game based learning’[Title/Abstract])) AND (Social*[Title/Abstract] OR ‘social conversation’[Title/Abstract] OR ‘social interaction’[Title/Abstract] OR ‘emotion*’[Title/Abstract] OR ‘face*’[Title/Abstract] OR ‘facial*’[Title/Abstract] OR feeling*[Title/Abstract] OR ‘expression*’[Title/Abstract] OR ‘turn taking’[Title/Abstract] OR ‘eye contact’[Title/Abstract] OR ‘joint attention’[Title/Abstract] OR ‘empath*’[Title/Abstract] OR ‘theory of mind’[Title/Abstract])

# Appendix B: Game information sources

**Table B.1. Information for each social emotional computer based intervention targeting autistic individuals**

| Article | Game | Information source |
|---|---|---|
| Bauminger et al. (2013) | NoProblem! | Zancanaro, M., Giusti, L., Gal, E., & Weiss, P. T. (2011, September). Three around a table: the facilitator role in a co-located interface for social competence training of children with autism spectrum disorder. In *IFIP Conference on Human-Computer Interaction* (pp. 123-140). Springer Berlin Heidelberg. |
| | JoinIn! | Zancanaro, M., Giusti, L., Bauminger-Zviely, N., Eden, S., Gal, E., & Weiss, P. L. (2014). NoProblem! A collaborative interface for teaching conversation skills to children with high functioning autism spectrum disorder. In *Playful User Interfaces* (pp. 209-224). Springer Singapore. |
| Beaumont & Sofronoff (2008) | Secret Agent Society | https://www.sst-institute.net/ (Video available) |
| Bernardini et al. (2014) | ECHOES | Article |
| Bernard-Opitz et al. (2001) | - | Article |
| Bölte et al. (2002, 2006, 2015) | Frankfurt Training for Facial Affect Recognition | Article (mainly from the 2002 article)<br>Bölte, S., Feineis-Matthews, S., Leber, S., Dierks, T., Hubl, D., & Poustka, F. (2002). The development and evaluation of a computer-based program to test and to teach the recognition of facial affect. *International Journal of Circumpolar Health*, *61*(sup2), 61-68.<br><br>https://ki.se/en/kind/fefa-a-computer-based-program-for-the-training-and-testing-of-facial-affect-recognition |
| Cheng et al. (2018) | 3D Complex Facial Expression Recognition (3CFER) | Article |
| Faja et al. (2012) | - | Faja, S., Aylward, E., Bernier, R., & Dawson, G. (2007). Becoming a face expert: A computerized face-training program for high-functioning individuals with autism spectrum disorders. *Developmental neuropsychology*, *33*(1), 1-24. |

| Article | Game | Information source |
| --- | --- | --- |
| Fletcher-Watson et al. (2015) | FindMe | http://www.interface3.com/findme/ (with video demos)<br><br>Fletcher-Watson, S., Hammond, S., O'Hare, A., Pain, H., Petrou, A., & McConachie, H. (2013, May). Click-East: evaluating the impact of an iPad app on social communicative abilities in young children with autism. In *International meeting for autism research*. |
| Fridenson-Hayo et al. (2017) | EmotiPlay | https://emotiplay.com/ |
| Friedrich et al. (2015) | - | Article |
| Golan and Baron-Cohen (2006); Lacava et al. (2007); Lacava et al. (2010); Lopata et al. (2016); Thomeer et al. (2011; 2015) | Mindreading | http://www.jkp.com/uk/mindreading/mainfeatures/ |
| Gordan et al. (2014) | FaceMaze | Article |
| Hopkins et al. (2011); Rice et al. (2015) | FaceSay | Article<br><br>http://www.facesay.com/ - free trial available for download |
| Jeffries et al, (2016) | Look in My Eyes Steam Train | https://www.youtube.com/watch?v=6jaRdZy0J18 |
| Jouen et al. (2017) | GOLIAH | Bono, V., Narzisi, A., Jouen, A.-L., Tilmont, E., Hommel, S., Jamal, W., … MICHELANGELO Study Group. (2016). GOLIAH: A Gaming Platform for Home-Based Intervention in Autism – Principles and Design. *Frontiers in Psychiatry*, *7*, 70. http://doi.org/10.3389/fpsyt.2016.00070 |
| Malinverni et al. (2017) | Pico's Adventures | Article<br>http://m4all.upf.edu/ (Main website)<br>http://m4all.upf.edu/?page_id=72 (Game Download)<br>Malinverni, L., Mora, J., Padillo, V., Hervás, A., Pares, N. (2014, October). Pico's Adventure: A Kinect game to promote social initiation in children with autism spectrum disorder. In *ITASD 2nd International Conference on Innovative Technologies* (pp. 1-7). |

| Article | Game | Information source |
|---|---|---|
| | | https://vimeo.com/94664626 (Video demonstration of game. Password provided in conference abstract) |
| Miller et al. (2017) | - | Article |
| Russo-Ponsaran et al. (2014, 2016) | MiX | https://www.youtube.com/watch?v=tm63UgaRdXo |
| Serret et al. (2014) | JeStiMulE | https://www.youtube.com/watch?v=3W-QaLE7hEo&feature=player_embedded |
| Silver & Oakes (2001) | Emotion Trainer | http://www.emotiontrainer.co.uk/ (demo available) |
| Swettenham (1996) | - | Article |
| Tanaka et al. (2010) | Let's Face It! | http://web.uvic.ca/~letsface/letsfaceit/<br>http://web.uvic.ca/~letsface/letsfaceit/?q=node/5<br>Free to download on website |
| White et al. (2018) | Facial Emotion Expression Training (FEET) | Article |

# Appendix C: Development of the serious game assessment tool

While it has been proposed that the application of Serious Game design frameworks will improve the effect of CBI (Whyte et al., 2015), evaluating this proposition has been limited by the lack of an available tool to quantify the application of these frameworks. In addressing this limitation, the first stage of this review undertook the development of a Serious Game Assessment Tool aimed at measuring the Serious Game design quality of social emotional CBI in ASD. Development of this tool followed a two stage process; initial development, content review and assessment reliability.

## *Stage 1: Initial development*

Initially, a literature review was completed to retrieve any relevant published articles describing principles or frameworks specifically for designing serious games. While there are a number of approaches to serious game design, the development of the Serious Game assessment tool for the present study was guided by a recent review Whyte et al. (2015), given its focus on the applicability of serious games in ASD. Whyte et al. (2015) provided a conceptual review of CBI in ASD based on the five serious game principles outlined, classifying whether the principle was present, absent or partially incorporated. For example, under the principle ‘motivating storyline’, games were either classified as ‘yes, signifying that it was present, ‘some’, or ‘themed’ if it was partially incorporated and ‘no’ indicating that the principle was not applied. ‘Some’ and ‘themed’ storylines were classified similarly as both features contains some motivating aspects for players to engage in. Additionally, ‘medium’ and ‘short’ term goals were both classified as ‘1’ as all serious games are designed to contain educational goals, rather than for the sole purpose of entertainment (Whyte et al., 2015). While the current framework articulates the grading of each Serious Game design principles, there is a need for clearer operational definitions of each of its classification. Given this, in the present review an ordinal classification system was developed through an iterative process, comparing and grading the range of game design features across existing CBI with respect to each of the five game design principles identified in Whyte et al. (2015). The total rating percentage was obtained by summing the total score relative to the maximum obtainable of score 10. The ordinal classification system for each principle is summarised in the table below.

**Table C.1. Description of the ordinal classification system in the Serious Game Assessment Tool**

| | Score/Rating scale | Description |
|---|---|---|
| Scores within each Serious Game principle | 2 | Principle fully incorporated in the CBI |
| | 1 | Principle partially incorporated in the CBI |
| | 0 | Principle is not applied in the CBI |
| Total rating percentage | 80% and above | Very strong application of Serious Game principles |
| | 70-79% | Good application of Serious Game principles |
| | 60-69% | Average application of Serious Game principles |
| | 49% and below | Limited application of Serious Game principles |

*Note.* CBI = computer based intervention.

## *Stage 2: Assessment reliability*

To increase the content clarity and reliability of the Serious Game Assessment Tool, social emotional CBIs in autism were retrieved and initially evaluated against the tool by the first author. A random selection of included CBI literature (20%) was examined by two reviewers (JT and MF) in determining the inter-rater reliability, resulting in further refinement of the proposed operational definitions of game design. A subsequent inter-rater reliability procedure (JT and SG) with a new randomly selected subset of CBI literature (20%) was conducted, achieving a kappa agreement score of $r_k$ = .96. Any remaining discrepancies were resolved with discussion. The final operational definitions and scoring matrix of the Serious Game Assessment Tool are presented in Table 3 embedded in the main manuscript.

# Appendix D: Outcome measurements and effect sizes

**Table D.1. Close generalisation outcomes**

| Author (Year) | Targeted outcome | Assessment | Intervention group | | | Control group | | | *F*-value | *t*-value | Between group effect size [95% CI] | Aggregated effect sizes [95% CI] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *n* | Pre Mean (SD) | Post Mean (SD) | *n* | Pre Mean (SD) | Post Mean (SD) | | | | |
| Beaumont & Sofronoff (2008) | Emotion recognition | Assessment of Perception of Emotion from Facial Expressions | 26 | 17.44 (2.67) | 19.92 (2.67) | 23 | 18.3 (2.46) | 19.73 (2.80) | - | - | 0.40 [-0.17, 0.97] | 0.94 [0.46, 1.41] |
| | | Assessment of Perception of Emotion from Posture cues | 26 | 20.48 (3.15) | 21.81 (2.97) | 23 | 20.96 (2.44) | 21.32 (2.82) | - | - | 0.34 [-0.23, 0.90] | |
| | Emotion regulation | James and the Maths Test (Attwood, 2004a) | 26 | 1.7 (1.07) | 3.81 (1.58) | 23 | 1.74 (1.21) | 2.00 (1.11) | - | - | 1.60 [0.96, 2.24] | |
| | | Dylan is Being Teased (Attwood, 2004b) | 26 | 2.93 (1.62) | 5.08 (2.23) | 23 | 2.78 (1.59) | 2.64 (1.56) | - | - | 1.40 [0.78, 2.03] | |
| Bölte et al. (2006) | Emotion recognition | Frankfurt Test of Facial Affect Recognition- Face | 5 | 31.6 (9.9) | 43.0 (3.2) | 5 | 33.6 (9.9) | 33.0 (9.4) | - | - | 1.09 [-0.23, 2.42] | 1.28 [0.10, 2.46] |
| | | Frankfurt Test of Facial Affect Recognition- Eyes | 5 | 17.6 (6.7) | 31.2 (4.9) | 5 | 21.4 (9.8) | 21.4 (9.5) | - | - | 1.46 [0.07, 2.86] | |
| Bölte et al. (2015) | Emotion recognition | Frankfurt Test of Facial Affect Recognition- Face and Eyes | 16 | 37.4 (7.2) | 43.7 (3.8) | 16 | 38.3 (6.0) | 39.1 (5.5) | - | - | 0.81 [-0.09, 1.53] | 0.71 [0.09, 1.33] |
| | | Emotion recognition Test | 16 | 15.8 (5.4) | 18.5 (5.6) | 16 | 16.8 (3.3) | 16.7 (5.5) | - | - | 0.61 [-0.10, 1.32] | |
| Faja et al. (2008) | Face processing | Benton Test of Facial Recognition-Long Form or Children's Memory Scale | 5 | - | - | 5 | - | - | 5.60 | - | 1.35 [0.08, 2.62] | 0.73 [-0.25, 1.71] |

| Author (Year) | Targeted outcome | Assessment | Intervention group | | | Control group | | | *F*-value | *t*-value | Between group effect size [95% CI] | Aggregated effect sizes [95% CI] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *n* | Pre Mean (SD) | Post Mean (SD) | *n* | Pre Mean (SD) | Post Mean (SD) | | | | |
| | | Sensitivity to second-order relations | 5 | - | - | 5 | - | - | - | 2.84 | 0.96 [-0.23, 2.15] | |
| | | Upright versus whole condition | 5 | - | - | 5 | - | - | - | 0.66 | 0.46 [-0.68, 1.60] | |
| | | Inversion effect | 5 | - | - | 5 | - | - | - | 1.11 | 0.60 [-0.54, 1.74] | |
| | | Holistic processing | 5 | - | - | 5 | - | - | - | 0.25 | 0.29 [-0.84, 1.42] | |
| Faja et al. (2012) | Face processing | Benton Test of Facial Recognition-Long Form or Children's Memory Scale | 5 | - | - | 5 | - | - | - | 1.37 | 0.53 [-0.37, 1.43] | 0.55 [-0.16, 1.26] |
| | | Sensitivity to second-order relations | 5 | - | - | 5 | - | - | 0.55 | - | 0.33 [-0.55, 1.21] | |
| | | Inversion effect | 5 | - | - | 5 | - | - | 5.13 | - | 1.02 [0.08, 1.96] | |
| | | Whole versus part conditions | 5 | - | - | 5 | - | - | 0.52 | - | 0.32 [-0.56, 1.20] | |
| Friedenson-Hayo et al. (2017) | Emotion recognition | Facial Expression Task*- Israel | 18 | 9.83 (3.43) | 12.11 (2.65) | 20 | 11.0 (2.22) | 11.3 (2.93) | - | - | 0.68 [0.02, 1.33] | 0.69 [0.18, 1.20] |
| | | Facial Expression Task*- Sweden | 16 | 10.0 (2.31) | 12.06 (2.82) | 20 | 10.05 (3.32) | 11.05 (3.35) | - | - | 0.36 [-0.31, 1.02] | |
| | | Voice Task*- Sweden | 18 | 10.47 (2.4) | 12.66 (2.45) | 20 | 11.0 (2.71) | 10.65 (2.72) | - | - | 0.97 [0.30, 1.64] | |
| | | Voice Task*- Israel | 16 | 11.19 (3.92) | 13.38 (3.34) | 20 | 11.63 (4.03) | 12.45 (4.26) | - | - | 0.34 [-0.54, 1.21] | |
| | | Body language Task*- Israel | 18 | 16.06 (3.93) | 20.0 (2.59) | 20 | 16.8 (3.49) | 16.1 (3.51) | - | - | 1.23 [0.53, 1.92] | |
| | | Body language Task*- Sweden | 16 | 13.25 (4.09) | 18.56 (3.18) | 20 | 14.7 (4.69) | 17.45 (4.12) | - | - | 0.56 [-0.11, 1.23] | |

| Author (Year) | Targeted outcome | Assessment | Intervention group | | | Control group | | | *F*-value | *t*-value | Between group effect size [95% CI] | Aggregated effect sizes [95% CI] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *n* | Pre Mean (SD) | Post Mean (SD) | *n* | Pre Mean (SD) | Post Mean (SD) | | | | |
| Golan & Baron-Cohen (2006)-1 | Emotion recognition | Cambridge Mindreading (CAM)- Face | 19 | 31.3 (8.8) | 37.5 (7.8) | 22 | 32.5 (8.4) | 34.8 (8.2) | - | - | 0.45 [-0.18, 1.07] | 0.51 [-0.00, 1.02] |
| | | Cambridge Mindreading (CAM)- Voice | 19 | 33.8 (6.6) | 38.9 (6.2) | 22 | 35.2 (7.4) | 36.6 (7.9) | - | - | 0.52 [-0.11, 1.14] | |
| | | Cambridge Mindreading (CAM)- Concepts recognised | 19 | 9.8 (5.2) | 13.6 (4.8) | 22 | 10.5 (5.2) | 11.3 (5.4) | - | - | 0.57 [-0.06, 1.19] | |
| Golan & Baron-Cohen (2006)-2 | Emotion recognition | Cambridge Mindreading (CAM)- Face | 13 | 32.3 (8.1) | 36.2 (8.9) | 13 | 26.8 (9.7) | 29.3 (9.5) | - | - | 0.15 [-0.62, 0.92] | 0.38 [-0.26, 1.01] |
| | | Cambridge Mindreading (CAM)- Voice | 13 | 33.2 (9.1) | 38.9 (7.6) | 13 | 31.1 (9.1) | 31.8 (10.9) | - | - | 0.53 [-0.25, 1.31] | |
| | | Cambridge Mindreading (CAM)- Concepts recognised | 13 | 10.2 (4.9) | 13.5 (5.2) | 13 | 7.7 (5.8) | 8.5 (6.3) | - | - | 0.45 [-0.33, 1.23] | |
| Hopkins et al. (2011) | Emotion recognition | Ekman's black and white photograph sand schematic drawings- HFA group | 13 | 8.0 (3.1) | 9.54 (2.34) | 11 | 6.31 (1.97) | 6.08 (2.33) | - | - | 0.64 [-0.18, 1.46] | 0.48 [-0.16, 1.12] |
| | | Ekman's black and white photograph sand schematic drawings- LFA group | 11 | 5.43 (2.59) | 6.57 (2.28) | 14 | 5.27 (1.95) | 5.18 (2.44) | - | - | 0.53 [-0.27, 1.33] | |
| | Face processing | Benton Facial Recognition Test (Long form) - HFA group | 13 | 36.0 (7.03) | 40.64 (6.67) | 11 | 29.31 (5.59) | 31.23 (5.79) | - | - | 0.41 [-0.40, 1.22] | |
| | | Benton Facial Recognition Test (Long form) - LFA group | 11 | 29.86 (4.72) | 32.64 (6.81) | 14 | 28.18 (4.21) | 29.36 (4.24) | - | - | 0.35 [-0.45, 1.14] | |
| Lopata et al. (2016) | Emotion recognition | Cambridge Mindreading (CAM)- Face | 18 | 25.61 (6.65) | 30.28 (6.670 | 18 | 23.78 (6.92) | 24.44 (7.27) | - | - | 0.58 [-0.09, 1.24] | 0.42 [-0.15, 0.99] |

| Author (Year) | Targeted outcome | Assessment | Intervention group | | | Control group | | | F-value | t-value | Between group effect size [95% CI] | Aggregated effect sizes [95% CI] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | n | Pre Mean (SD) | Post Mean (SD) | n | Pre Mean (SD) | Post Mean (SD) | | | | |
| | | Cambridge Mindreading (CAM)- Voice | 18 | 25.94 (6.67) | 29.17 (7.23) | 18 | 23.39 (6.62) | 24.83 (7.79) | - | - | 0.26 [-0.39, 0.92] | |
| Rice et al. (2015) | Emotion recognition | NEPSY-II Affect Recognition subtest | 16 | 8.63 (3.36) | 12.56 (2.71) | 15 | 8.73 (2.55) | 8.53 (3.18) | - | - | 1.34 [0.56, 2.12] | - |
| Russo-Ponsaran et al. (2016) | Emotion recognition | NEPSY-II Affect Recognition subtest | 12 | 24.25 (5.03) | 28.24 (2.8) | 13 | 23.77 (6.3) | 26.71 (2.7) | - | - | 0.18 [-0.61, 0.96] | 1.07 [0.42, 1.72] |
| | | MiX* | 12 | 49.5 (24.0) | 99.07 (12.5) | 13 | 66.7 (21.9) | 63.55 (12.5) | - | - | 2.22 [1.23, 3.22] | |
| | | Diagnostic Analysis of Nonverbal Accuracy-Child Faces Test | 12 | 76.4 (13.6) | 83.65 (9.9) | 13 | 77.6 (12.7) | 76.31 (9.9) | - | - | 0.63 [0.18, 1.43] | |
| | | Comprehensive affective testing (Names Affect subtest) | 12 | 63.5 (17.6) | 72.64 (9.5) | 13 | 64.4 (17.4) | 67.56 (9.5) | - | - | 0.33 [-0.46, 1.12] | |
| | | Comprehensive affective testing (Three Faces subtest) | 12 | 52.1 (9.6) | 61.61 (9.0) | 13 | 51.9 (11.2) | 56.8 (8.9) | - | - | 0.43 [-0.37, 1.22] | |
| | Emotion imitation | Video ratings of quality of facial expressions- Sad | 12 | 0.83 (0.39) | 1.19 (0.6) | 13 | 1.0 (0.0) | 1.06 (0.6) | - | - | 1.08 [0.24, 1.91] | |
| | | Video ratings of quality of facial expressions- Anger | 12 | 1.25 (0.45) | 1.88 (0.5) | 13 | 1.31 (0.63) | 1.26 (0.5) | - | - | 1.20 [0.35, 2.05] | |
| | | Video ratings of quality of facial expressions- Disgust | 12 | 0.83 (0.58) | 1.90 (0.5) | 13 | 1.23 (0.44) | 0.94 (0.5) | - | - | 2.57 [2.13, 3.63] | |
| | | Video ratings of quality of facial expressions- Contempt | 12 | 0.75 (0.75) | 2.10 (0.5) | 13 | 1.00 (0.71) | 0.75 (0.5) | - | - | 2.58 [1.70, 3.46] | |
| | | Video ratings of quality of facial expressions- Fear | 12 | 1.17 (0.5) | 1.24 (0.5) | 13 | 1.00 (0.41) | 1.40 (0.5) | - | - | -0.81 [-1.62, 0.01] | |

| Author (Year) | Targeted outcome | Assessment | Intervention group | | | Control group | | | *F*-value | *t*-value | Between group effect size [95% CI] | Aggregated effect sizes [95% CI] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *n* | Pre Mean (SD) | Post Mean (SD) | *n* | Pre Mean (SD) | Post Mean (SD) | | | | |
| | | Video ratings of quality of facial expressions- Surprise | 12 | 1.42 (0.52) | 1.96 (0.5) | 13 | 1.54 (0.52) | 1.35 (0.5) | - | - | 1.36 [0.92, 1.80] | |
| Silver & Oakes (2001) | Emotion recognition | Facial Expression Photographs (Spence, 1980) | 11 | 4.27 (1.85) | - | 11 | 4.45 (2.34) | - | 5.57 | - | 0.97 [0.12, 1.82] | 0.94 [0.20, 1.67] |
| | | Emotion Recognition Cartoons. | 11 | 4.36 (3.35) | - | 11 | 3.27 (1.79) | - | 4.79 | - | 0.90 [0.05, 1.75] | |
| Tanaka et al. (2010) | Emotion recognition | Let's Face It! Skills Battery* Expression subtest | 42 | 49.1 | 64.1 | 37 | 56.4 | 52.0 | 0.0 | - | 0.00 [-0.44, 0.44] | 0.23 [-0.11, 0.57] |
| | Face processing | Let's Face It! Skills Battery* Face dimensions subtest | 42 | 72.1 | 79.8 | 37 | 74.2 | 81.0 | 0.20 | - | 0.10 [-0.34, 0.54] | |
| | | Let's Face It! Skills Battery* immediate memory for faces subtest | 42 | 43.1 | 43.0 | 37 | 46.3 | 49.2 | 0.47 | - | 0.15 [-0.29, 0.59] | |
| | | Let's Face It! Skills Battery* masked features subtest | 42 | 52.1 | 58.1 | 37 | 54.6 | 58.5 | 0.77 | - | 0.20 [-0.24, 0.64] | |
| | | Let's Face It! Skills Battery* parts/whole identity subtest | 42 | 58.3 | 64.1 | 37 | 63.3 | 63.1 | 9.15 | - | 0.68 [0.24, 1.12] | |
| Thomeer et al. (2015) | Emotion recognition | Cambridge Mindreading (CAM)- Face | 22 | 23.05 (8.77) | 32.71 (6.04) | 21 | 24.48 (6.99) | 24.71 (7.13) | - | - | 1.16 [0.52, 1.81] | 1.03 [0.48, 1.58] |
| | | Cambridge Mindreading (CAM)- Voice | 22 | 22.95 (7.99) | 30.95 (7.66) | 21 | 22.1 (6.56) | 23.38 (6.41) | - | - | 0.90 [0.27, 1.53] | |

*Note.* CI = Confidence interval; HFA = High functioning autism; LFA = Low functioning autism; n = Number of participants; SD = Standard deviation; * Assessment modified or developed by authors.

**Table D.2. Distant generalisation outcomes**

| Author (Year) | Targeted outcome | Assessment | Intervention group | | | Control group | | | Between group effect size [95% CI] | Aggregated effect sizes [95% CI] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | *n* | Pre-Mean (SD) | Post-Mean (SD) | *n* | Pre-Mean (SD) | Post-Mean (SD) | | |
| Beaumont & Sofronoff (2008) | Emotion regulation | Emotion Regulation and Social Skills Questionnaire (parent report) | 26 | 39.78 (10.17) | 57.38 (13.4) | 23 | 39.64 (12.52) | 40.14 (10.69) | 1.48 [0.85, 2.12] | - |
| Fletcher-Watson et al. (2015) | Social communication | Communication and Symbolic Behaviour Scale- communicative behaviours. | 26 | 23.8 (6.2) | 24.9 (6.0) | 23 | 24.5 (6.1) | 24.9 (5.2) | 0.11 [-0.43, 0.65] | 0.14 [-0.33, 0.61] |
| | | Communication and Symbolic Behaviour Scale- symbolic behaviours. | 26 | 6.6 (2.5) | 6.9 (2.3) | 23 | 7.1 (2.1) | 7.0 (2.2) | 0.17 [-0.37, 0.71] | |
| Friedenson-Hayo et al. (2017) | Emotion recognition | Emotion Integrative Task*- Israel | 18 | 11.94 (2.55) | 12.72 (3.08) | 20 | 12.45 (2.48) | 12.10 (3.49) | 0.44 [-0.20, 1.08] | 0.34 [-0.23, 0.90] |
| | | Emotion Integrative Task*- Sweden | 16 | 9.31 (2.68) | 12.19 (3.12) | 20 | 10.05 (3.38) | 12.2 (3.53) | 0.23 [-0.43, 0.89] | |
| Golan & Baron-Cohen (2006)-1 | Emotion recognition | Reading the Mind in the Eyes Task | 19 | 23.1 (6.7) | 23.8 (4.7) | 22 | 23.9 (6.7) | 23.0 (7.3) | 0.23 [-0.38, 0.85] | 0.03 [-0.50, 0.56] |
| | | Reading the Mind in the Voice Task | 19 | 16.1 (3.9) | 16.7 (3.9) | 22 | 16.1 (3.9) | 17.4 (3.5) | -0.18 [-0.79, 0.44] | |
| Golan & Baron-Cohen (2006)-2 | Emotion recognition | Reading the Mind in the Eyes Task | 13 | 21.6 (6.3) | 23.8 (4.2) | 13 | 21.5 (5.6) | 19.2 (6.8) | 0.73 [-0.06, 1.53] | 0.40 [-0.27. 1.08] |
| | | Reading the Mind in the Voice Task | 13 | 15.1 (2.8) | 16.2 (3.5) | 13 | 13.9 (4.5) | 14.7 (4.6) | 0.08 [-0.69, 0.85] | |
| Lopata et al. (2016) | Emotion recognition | Emotion recognition survey- parent report | 18 | 77.56 (16.09) | 92.94 (17.84) | 18 | 90.79 (18.19) | 100.14 (19.99) | 0.34 [-0.31, 1.00] | 0.10 [-0.44, 0.63] |

| Author (Year) | Targeted outcome | Assessment | Intervention group | | | Control group | | | Between group effect size [95% CI] | Aggregated effect sizes [95% CI] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | *n* | Pre-Mean (SD) | Post-Mean (SD) | *n* | Pre-Mean (SD) | Post-Mean (SD) | | |
| | | Emotion recognition survey- clinician ratings | 18 | 84.4 (16.09) | 99.21 (17.84) | 18 | 93.89 (17.8) | 105.55 (13.39) | 0.18 [-0.47, 0.84] | |
| | | Social emotional evaluation | 18 | 49.33 (6.86) | 50.5 (7.29) | 18 | 50.22 (4.04) | 52.72 (2.76) | -0.23 [-0.89, 0.42] | |
| Russo-Ponsaran et al. (2016) | Emotion awareness | Emotion Fluency | 12 | 8.42 (3.4) | 6.38 (4.3) | 13 | 8.54 (4.9) | 6.58 (4.2) | -0.02 [-0.80, 0.77] | 0.63 [-0.04, 1.30] |
| | | Emotion Storybook | 12 | 6.58 (8.9) | 6.27 (4.2) | 13 | 13.77 (15.18) | 6.59 (4.2) | 0.53 [-0.27, 1.33] | |
| | Emotion recognition | Child and Adolescent Social Perception Scale | 12 | 26.94 (13.14) | 42.62 (10.4) | 13 | 34.7 (14.66) | 30.6 (10.3) | 1.37 [0.50, 2.24] | |
| Thomeer et al. (2015) | Emotion recognition | Emotion recognition survey | 22 | 93.45 (21.87) | 119.5 (20.41) | 21 | 101.43 (23.16) | 114.05 (22.66) | 0.86 [0.24, 1.49] | 0.72 [0.19, 1.26] |
| | Emotion imitation | Emotion Display survey | 22 | 107.64 (13.25) | 130.59 (18.59) | 21 | 120.43 (25.16) | 125.81 (21.59) | 0.59 [-0.02, 1.20] | |

*Note.* CI = Confidence interval; n = Number of participants; SD = Standard deviation; * Assessment modified or developed by authors.

**Table D.3. Transferability outcomes**

| Author (Year) | Targeted outcome | Assessment | Intervention group | | | Control group | | | *F*-value | Between group effect size [95% CI] | Aggregated effect sizes [95% CI] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *n* | Pre-Mean (SD) | Post-Mean (SD) | *n* | Pre-Mean (SD) | Post-Mean (SD) | | | |
| Beaumont & Sofronoff (2008) | Social skills | Social Skills Questionnaire- parent report | 26 | 25.3 (7.43) | 38.08 (9.84) | 23 | 23.16 (9.05) | 25.11 (7.91) | - | 1.30 [0.68, 1.91] | - |
| Bölte et al. (2006) | Brain activation | fMRI Fusiform gyrus-right | 5 | 1.38 (0.59) | 1.04 (0.29) | 23 | 1.13 (0.32) | 1.07 (0.16) | - | -0.53 [-1.79, 0.73] | 0.60 [-0.40, 1.60] |
| | | fMRI Fusiform gyrus-left | 5 | 1.14 (0.2) | 1.08 (0.49) | 23 | 1.07 (0.21) | 1.11 (0.31) | - | -0.44 [-1.69, 0.81] | |
| | | fMRI Medical occipital gyrus-right | 5 | 1.41 (0.36) | 1.42 (0.59) | 23 | 1.46 (0.48) | 0.95 (0.29) | - | 1.11 [-0.22, 2.44] | |
| | | fMRI Medical occipital gyrus-left | 5 | 1.64 (0.62) | 1.66 (0.61) | 23 | 1.58 (0.42) | 1.01 (0.36) | - | 1.01 [-0.31, 2.32] | |
| | | fMRI Precentral gyrus-right | 5 | 1.28 (0.3) | 0.99 (0.43) | 23 | 0.89 (0.28) | 0.86 (0.13) | - | -0.81 [-2.10, 0.48] | |
| | | fMRI Precentral gyrus-left | 5 | 1.09 (0.15) | 1.16 (0.53) | 23 | 0.88 (0.29) | 0.66 (0.31) | - | 1.13 [-0.20, 2.47] | |
| | | fMRI Superior parietal lobule- right | 5 | 0.58 (0.16) | 1.16 (0.13) | 23 | 0.86 (0.45) | 0.78 (0.17) | - | 1.76 [0.30, 3.23] | |
| | | fMRI Superior parietal lobule- left | 5 | 0.95 (0.16) | 1.10 (0.38) | 23 | 1.13 (0.42) | 0.72 (0.28) | - | 1.59 [0.17, 3.01] | |
| Faja et al. (2012) | Brain activation | Event Related Potentials (P1 amplitude) | 9 | - | - | 9 | - | - | 4.8 | 1.25 [0.01, 2.49] | - |
| Fletcher-Watson et al. (2015) | Language skills | MacArthur Communicative Development Inventory-words | 26 | 207.0 (135) | 223.0 (140) | 27 | 203.0 (129) | 221.0 (132) | - | -0.01 [-0.55, 0.52] | 0.03 [-0.41, 0.47] |
| | | MacArthur Communicative Development Inventory- | 26 | 142.0 (156) | 162.0 (163) | 27 | 123.0 (138) | 148.0 (155) | - | -0.03 [-0.57, 0.51] | |

| Author (Year) | Targeted outcome | Assessment | Intervention group | | | Control group | | | *F*-value | Between group effect size [95% CI] | Aggregated effect sizes [95% CI] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *n* | Pre-Mean (SD) | Post-Mean (SD) | *n* | Pre-Mean (SD) | Post-Mean (SD) | | | |
| | | MacArthur Communicative Development Inventory-gestures | 26 | 30.0 (15.1) | 31.0 (16.4) | 27 | 33.0 (15.2) | 32.0 (15.2) | - | 0.13 [-0.41, 0.67] | |
| Hopkins et al. (2011) | Social Skills | Social Skills Observation- HFA | 11 | 8.68 (2.11) | 7.72 (2.56) | 13 | 8.85 (2.58) | 10.31 (0.97) | - | -0.98 [-1.83, -0.13] | 0.01 [-0.64, 0.66] |
| | | Social Skills Observation- LFA | 14 | 9.86 (2.48) | 9.68 (1.71) | 11 | 10.14 (2.17) | 10.95 (1.42) | - | -0.41 [-1.21, 0.39] | |
| | | Social Skills Rating System- HFA | 11 | 61.55 (9.43) | 63.9 (8.84) | 13 | 68.38 (7.13) | 66.78 (10.68) | - | 0.46 [-0.35, 1.28] | |
| | | Social Skills Rating System- LFA | 14 | 61.71 (8.62) | 68.64 (9.93) | 11 | 60.91 (8.39) | 59.45 (9.49) | - | 0.95 [0.12, 1.78] | |
| Jouen et al. (2017) | Autism symptomatology | Social Communication Questionnaire | 14 | 11.6 (7.7) | 10.0 (6.3) | 10 | 11.5 (7.2) | 8.6 (7.0) | - | 0.17 [-0.65, 0.98] | -0.03 [-0.66, 0.59] |
| | | Autism Diagnostic Observation Schedule | 14 | 10.8 (3.6) | 9.2 (4.6) | 10 | 13.8 (3.5) | 11.0 (4.1) | - | -0.32 [-1.14, 0.50] | |
| | Adaptive behaviour | Vineland Adaptive Behaviour Scale II- Communication | 14 | 88.2 (16.7) | 79.6 (11.5) | 10 | 86.2 (13.9) | 82.8 (6.5) | - | -0.56 [-1.39, 0.26] | |
| | | Vineland Adaptive Behaviour Scale II- Socialisation | 14 | 79.5 (10.3) | 78.3 (10.7) | 10 | 80.1 (11.9) | 85.3 (8.4) | - | -0.21 [-1.03, 0.60] | |
| | | Vineland Adaptive Behaviour Scale II- Daily Living | 14 | 84.3 (13.4) | 79.4 (5.5) | 10 | 85.4 (14.7) | 83.6 (10.8) | - | 0.33 [-0.49, 1.14] | |
| | Behaviour | Child Behaviour Checklist | 14 | 63.9 (8.4) | 61.2 (8.3) | 10 | 66.5 (7.3) | 60.5 (11.3) | - | 0.40[-0.42, 1.22] | |
| Lopata et al. (2016) | | Social Responsiveness Scale- researcher | 18 | 58.22 (10.65) | 65.22 (7.39) | 18 | 60.33 (9.71) | 67.11 (7.07) | - | 0.02 [-0.63, 0.67] | 0.08 [-0.42, 0.58] |

| Author (Year) | Targeted outcome | Assessment | Intervention group | | | Control group | | | *F*-value | Between group effect size [95% CI] | Aggregated effect sizes [95% CI] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *n* | Pre-Mean (SD) | Post-Mean (SD) | *n* | Pre-Mean (SD) | Post-Mean (SD) | | | |
| | Autism symptomatology | ratings (scores reversed) | | | | | | | | | |
| | | Social Responsiveness Scale- parent ratings (scores reversed) | 18 | 71.28 (13.11) | 81.83 (10.24) | 18 | 71.61 (12.89) | 84.11 (10.71) | - | -0.15 [-0.80, 0.51] | |
| | Social skills | Adapted Skillsstreaming Checklist- parent ratings | 18 | 101.94 (18.04) | 117.33 (17.29) | 18 | 99.11 (16.98) | 116.89 (16.85) | - | -0.13 [-0.79, 0.52] | |
| | | Adapted Skillsstreaming Checklist- researcher ratings | 18 | 102.06 (26.15) | 124.89 (30.0) | 18 | 101.72 (20.11) | 124.78 (19.7) | - | -0.01 [-0.66, 0.64] | |
| | | Behaviour Assessment System for Children- researcher ratings | 18 | 42.56 (9.1) | 49.61 (8.37) | 18 | 42.61 (4.89) | 47.44 (6.25) | - | 0.30 [-0.36, 0.95] | |
| | | Behaviour Assessment System for Children- parent ratings | 18 | 33.89 (7.48) | 38.56 (8.21) | 18 | 37.44 (9.91) | 38.11 (8.55) | - | 0.45 [-0.22, 1.11] | |
| Rice et al. (2015) | Theory of mind | NEPSY-II Theory of Mind Subtest | 16 | 15.38 (5.83) | 21.63 (4.83) | 15 | 14.8 (7.35) | 16.6 (6.9) | - | 0.66 [-0.07, 1.38] | 0.19 [-0.37, 0.75] |
| | Autism Symptomatology | Social Responsiveness Scale (scores reversed) | 16 | 62.25 (9.34) | 65.19 (7.66) | 15 | 67.8 (10.05) | 65.4 (9.91) | - | -0.59 [-1.31, 0.13] | |
| | Social skills | Positive interactions- observations | 16 | 6.47 (3.73) | 6.47 (4.37) | 15 | 7.2 (3.45) | 7.87 (3.53) | - | -0.18 [-0.89, 0.52] | |
| | | Negative interactions- observations (scores reversed) | 16 | 0.56 (0.95) | 1.0 (0.93) | 15 | 0.17 (0.36) | 0.8 (1.0) | - | -0.25 [-0.96, 0.45] | |

| Author (Year) | Targeted outcome | Assessment | Intervention group | | | Control group | | | *F*-value | Between group effect size [95% CI] | Aggregated effect sizes [95% CI] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *n* | Pre-Mean (SD) | Post-Mean (SD) | *n* | Pre-Mean (SD) | Post-Mean (SD) | | | |
| Russo-Ponsaran et al. (2016) | Social skills | Bar-On Emotional Quotient Inventory: Youth Version | 12 | 67.75 (11.71) | 64.26 (6.3) | 13 | 58.92 (7.25) | 62.26 (6.3) | - | -0.68 [-1.49, 0.12] | - |
| Silver & Oakes (2001) | Theory of mind | Happe’s Strange Stories | 11 | 18.3 | 16.4 | 11 | 20.8 | 22.9 | 6.88 | 1.08 [0.23, 1.93] | - |
| Thomeer et al. (2015) | Social skills | Behaviour Assessment System for Children, Second Edition- Parent Rating Scales | 22 | 38.18 (11.13) | 40.68 (10.29) | 21 | 36.95 (8.29) | 37.76 (7.86) | - | 0.17 [-0.43, 0.77] | 0.36 [-0.17, 0.88] |
| | Autism symptomato logy | Social Responsiveness Scale | 22 | 75.59 (13.05) | 83.86 (13.14) | 21 | 78.81 (10.8 7) | 80.38 (13.9 1) | - | 0.55 [-0.06, 1.16] | |

*Note.* CI = Confidence interval; fMRI = Functional magnetic resonance imaging; HFA = High functioning autism; LFA = Low functioning autism; n = Number of participants; SD = Standard deviation.

**Table D.4. Maintenance outcomes**

| Author (Year) | Targeted outcome | Assessment | Duration post intervention | Intervention group | | | Control group | | | Between group effect size [95% CI] | Aggregated effect sizes [95% CI] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | *n* | Pre-Mean (SD) | Post-Mean (SD) | *n* | Pre-Mean (SD) | Post-Mean (SD) | | |
| **Close generalisation** | | | | | | | | | | | |
| Beaumont & Sofronoff (2008) | Emotion recognition | Assessment of Perception of Emotion from Facial Expression | 6 weeks | 25 | 17.4 (2.75) | 20.32 (4.76) | 23 | 19.35 (2.82) | 21.35 (2.31) | 0.33 [-0.24, 0.90] | -0.09 [-0.55, 0.36] |
| | | Assessment of Perception of Emotion from Posture Cues | 6 weeks | 25 | 20.44 (3.16) | 22.2 (2.52) | 23 | 21.57 (2.76) | 22.91 (1.98) | 0.14 [-0.43, 0.71] | |
| | Emotion management | James and the Maths Test- anxiety management | 6 weeks | 25 | 1.76 (1.09) | 2.76 (1.33) | 21 | 1.91 (0.95) | 3.48 (2.02) | -0.54 [-1.14, 0.05] | |
| | | Dylan is Being Teased (presented with a story and asked to offer suggestions)- | 6 weeks | 25 | 3.0 (1.55) | 4.36 (2.27) | 21 | 2.39 (1.67) | 4.22 (2.32) | -0.29 [-0.87, 0.30] | |
| Russo-Ponsaran et al. (2016) | Emotion recognition | NEPSY Affect Recognition- | 4-6 weeks | 12 | 24.25 (5.03) | 27.33 (2.7) | 13 | 23.77 (6.3) | 24.69 (2.7) | 0.36 [-0.43, 1.16] | 0.88 [0.25, 1.51] |
| | | Mix (developed by authors)- emotion labeling of child faces- | 4-6 weeks | 12 | 49.5 (24.0) | 94.62 (13.9) | 13 | 66.7 (21.9) | 61.74 (13.8) | 2.11 [1.13, 3.09] | |
| | | Diagnostic Analysis of Nonverbal Accuracy (Child Faces) | 4-6 weeks | 12 | 76.4 (13.6) | 80.45 (8.2) | 13 | 77.6 (12.7) | 74.14 (8.2) | 0.55 [-0.25, 1.35] | |
| | | Comprehensive Affect Testing System (Three Faces)- | 4-6 weeks | 12 | 52.1 (9.6) | 60.6 (10.2) | 13 | 51.9 (11.2) | 59.66 (10.2) | 0.07 [-0.72, 0.85] | |
| | | Comprehensive Affect Testing System (Name Affect)- | 4-6 weeks | 12 | 63.5 (17.6) | 75.68 (11.4) | 13 | 64.4 (17.4) | 75.81 (11.4) | 0.04 [-0.74, 0.83] | |

| Author (Year) | Targeted outcome | Assessment | Duration post interventio n | Intervention group | | | Control group | | | Between group effect size [95% CI] | Aggregated effect sizes [95% CI] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | *n* | Pre-Mean (SD) | Post-Mean (SD) | *n* | Pre-Mean (SD) | Post-Mean (SD) | | |
| | Emotion imitation | Video recordings of emotion imitation- Sad- | 4-6 weeks | 4 | 0.83 (0.39) | 1.25 (0.6) | 13 | 1.0 (0.0) | 0.94 (0.6) | 1.72 [0.80, 2.64] | |
| | | Video recordings of emotion imitation- Anger- | 4-6 weeks | 4 | 1.25 (0.45) | 1.72 (0.52) | 13 | 1.31 (0.63) | 1.19 (0.5) | 1.03 [0.20, 1.87] | |
| | | Video recordings of emotion imitation- Disgust- | 4-6 weeks | 4 | 0.83 (0.58) | 1.6 (0.5) | 13 | 1.23 (0.44) | 1.29 (0.5) | 1.34 [0.47, 2.21] | |
| | | Video recordings of emotion imitation- Contempt- | 4-6 weeks | 4 | 0.75 (0.45) | 1.92 (0.6) | 13 | 1.0 (0.71) | 1.07 (0.6) | 1.77 [0.85, 2.70] | |
| | | Video recordings of emotion imitation- Fear- | 4-6 weeks | 4 | 1.17 (0.39) | 1.06 (0.5) | 13 | 1.0 (0.41) | 1.19 (0.5) | -0.72 [-1.53, 0.09] | |
| | | Video recordings of emotion imitation- Surprise- | 4-6 weeks | 4 | 1.42 (0.52) | 1.86 (0.6) | 13 | 1.54 (0.52) | 1.21 (0.6) | 1.43 [0.55, 2.31] | |
| Thomeer et al. (2015) | Emotion recognition | Cambridge Mindreading Face Battery | 5 weeks | 4 | 23.05 (8.77) | 31.68 (6.04) | 21 | 24.48 (6.99) | 24.71 (7.13) | 1.04 [0.40, 1.67] | 0.86 [0.32, 1.40] |
| | | Cambridge Mindreading Voice Battery- Children | 5 weeks | 4 | 22.95 (7.99) | 31.27 (8.76) | 21 | 22.1 (6.56) | 25.33 (7.16) | 0.68 [0.07, 1.30] | |
| **Distant generalisation** | | | | | | | | | | | |
| Beaumont & Sofronoff (2008) | Emotion regulation | Emotion regulation and social skills questionnaire- parent report- | 6 weeks | 25 | 39.78 (10.17) | 64.24 (9.27) | 21 | 39.96 (10.27) | 58.61 (11.99) | 0.56 [-0.03, 1.15] | 0.33 [-0.17, 0.84] |
| | | Emotion regulation and social skills | 5 months | 25 | 39.78 (10.17) | 62.12 (12.9) | 21 | 39.96 (10.27) | 61.19 (10.96) | 0.11 [-0.47, 0.69] | |

| Author (Year) | Targeted outcome | Assessment | Duration post intervention | Intervention group | | | Control group | | | Between group effect size [95% CI] | Aggregated effect sizes [95% CI] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | *n* | Pre-Mean (SD) | Post-Mean (SD) | *n* | Pre-Mean (SD) | Post-Mean (SD) | | |
| | | questionnaire- parent report- | | | | | | | | | |
| Fletcher-Watson et al. (2015) | Social communication | Scripted interview (with parents)- communication scales- Developmental Profile and Gaming- | 6 months | 24 | 23.8 (6.2) | 25.3 (5.8) | 25 | 24.5 (6.1) | 27.3 (5.9) | -0.21 [-0.77, 0.35] | -0.02 [-0.48, 0.44] |
| | | Scripted interview (with parents)- symbolic behaviour scales- Developmental Profile and Gaming - | 6 months | 24 | 6.6 (2.5) | 7.1 (2.7) | 25 | 7.1 (2.1) | 7.7 (2.4) | -0.04 [-0.60, 0.52] | |
| | | Brief observation of social communication change- | 6 months | 24 | 24.6 (8.5) | 24.7 (8.0) | 25 | 25.5 (8.3) | 23.9 (8.4) | 0.20 [-0.36, 0.76] | |
| Russo-Ponsaran et al. (2016) | Emotion recognition | Child and Adolescent Social Perception Scale- six videos of social interactions- | 4-6 weeks | 12 | 26.94 (13.14) | 37.28 (10.5) | 13 | 34.7 (14.66) | 32.67 (10.5) | 0.86 [0.04, 1.68] | 0.48 [-0.18, 1.13] |
| | Emotion awareness | Emotion fluency (recite emotional words)- | 4-6 weeks | 12 | 8.42 (3.4) | 7.56 (3.9) | 13 | 8.54 (4.9) | 7.71 (3.9) | -0.01 [-0.79, 0.78] | |
| | | Emotion storybook (spontaneity in using emotion words)- create a story from a wordless book- | 4-6 weeks | 12 | 6.58 (8.9) | 7.82 (3.9) | 13 | 13.77 (15.18) | 7.53 (3.8) | 0.58 [-0.23, 1.38] | |
| Thomeer et al. (2015) | Emotion recognition | Emotion recognition survey (parent report) | 5 weeks | 22 | 93.45 (21.87) | 121.23 (26.76) | 21 | 101.43 (23.16) | 108.0 (22.47) | 0.92 [0.30, 1.55] | 1.10 [0.54, 1.66] |

| Author (Year) | Targeted outcome | Assessment | Duration post intervention | Intervention group | | | Control group | | | Between group effect size [95% CI] | Aggregated effect sizes [95% CI] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | *n* | Pre-Mean (SD) | Post-Mean (SD) | *n* | Pre-Mean (SD) | Post-Mean (SD) | | |
| | Emotion imitation | Emotion recognition display survey (parent report) | 5 weeks | 22 | 107.64 (13.25) | 132.23 (25.89 ) | 21 | 120.43 (25.16) | 119.05 (20.32) | 1.28 [0.62, 1.93] | |
| **Transferability outcomes** | | | | | | | | | | | |
| Beaumont & Sofronoff (2008) | Social skills | Social Skills Questionnaire (Parent report) | 6 weeks | 25 | 25.3 (7.43) | 43.24 (8.81) | 21 | 25.09 (7.34) | 39.96 (9.46) | 0.41 [-0.18, 0.99] | 0.24 [-0.22, 0.71] |
| | | Social Skills Questionnaire (Parent report) | 5 months | 25 | 25.3 (7.43) | 40.64 (12.85) | 21 | 25.09 (7.34) | 41.17 (8.48) | -0.10 [-0.68, 0.48] | |
| | | Emotion regulation and social skills questionnaire | 6 weeks | 25 | 39.78 (10.17 ) | 64.24 (9.27) | 21 | 39.96 (10.27) | 58.61 (11.99) | 0.56 [-0.03, 1.15] | |
| | | Emotion regulation and social skills questionnaire | 5 months | 25 | 39.78 (10.17 ) | 62.12 (12.9) | 21 | 39.96 (10.27) | 61.19 (10.96) | 0.11 [-0.47, 0.69] | |
| Fletcher-Watson et al. (2015) | Autism symptomatology | Autism diagnostic Observation Schedule- Overall (scores reversed) | 6 months | 24 | 15.1 (7.0) | 16.7 (5.8) | 25 | 13.6 (6.9) | 15.9 (5.7) | -0.10 [0.66, 0.46] | -0.05 [-0.50, 0.39] |
| | Language skills | MacArthur Communicative Development Inventory- words understood | 6 months | 24 | 207.0 (135.0 ) | 226.0 (138.0) | 25 | 203.0 (129.0) | 247.0 (141.0) | -0.19 [-0.75, 0.37] | |
| | | MacArthur Communicative Development Inventory- words produced | 6 months | 24 | 142.0 (156.0 ) | 167.0 (165) | 25 | 123.0 (138.0) | 178.0 (165.0) | -0.20 [-0.76, 0.36] | |
| | | MacArthur Communicative | 6 months | 24 | 30.0 (15.1) | 36.0 (17.4) | 25 | 33.0 (14.4) | 35.0 (17.5) | 0.27 [-0.30, 0.83] | |

| Author (Year) | Targeted outcome | Assessment | Duration post intervention | Intervention group | | | Control group | | | Between group effect size [95% CI] | Aggregated effect sizes [95% CI] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | *n* | Pre-Mean (SD) | Post-Mean (SD) | *n* | Pre-Mean (SD) | Post-Mean (SD) | | |
| | | Development Inventory- gestures | | | | | | | | | |
| Russo-Ponsaran et al. (2016) | Social skills | Bar-On Emotional Quotient Inventory | 4-6 weeks | 12 | 67.75 (11.71) | 64.18 (9.3) | 13 | 58.92 (7.25) | 62.84 (9.2) | -0.75 [-1.56, 0.06] | -0.75 [-1.56, 0.06] |
| Thomeer et al. (2015) | Social skills | Behaviour assessment system for children-2nd edition | 5 weeks | 22 | 38.18 (11.13) | 40.82 (9.02) | 21 | 36.95 (8.29) | 38.67 (7.58) | 0.09 [-0.51, 0.69] | 0.32 [-0.20, 0.84] |
| | Autism symptomatology | Social Responsiveness Scale (scores reversed) | 5 weeks | 22 | 76.27 (12.96) | 83.86 (13.14) | 21 | 79.43 (10.56) | 80.38 (13.91) | 0.55 [-0.06, 1.16] | |

*Note.* CI = Confidence interval; n = Number of participants; SD = Standard deviation.

# Appendix E: Quality assessment of studies

### Table E.1. Quality assessment of studies

| Author (Year) | Criteria for quality assessment of included studies | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Question/objective sufficiently described? | Study design evident and appropriate? | Method of subject/comparison group selection or source of information/input variables described? | Subject and comparison group characteristics sufficiently described? | If interventional and random allocation was possible, was it described? | If interventional and blinding of investigators was possible, was it reported? | If interventional and blinding of subjects was possible, was it reported? | Outcome and exposure measure(s) well defined and robust to measurement/misclassification bias? Means of assessment reported? | Sample size appropriate? | Analytic methods described and appropriate? | Some estimate of variance is reported for the main results? | Controlled for confounding? | Results reported in sufficient detail? | Conclusions supported by the result? |
| Bauminger-Zviely, et al. (2013) | Yes | Partial | Partial | Yes | No | No | No | Yes | Partial | Partial | Yes | Partial | Yes | Yes |
| Beaumont & Sofronoff (2008) | Yes | Yes | Yes | Yes | Partial | No | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Bernardini et al. (2014) | Partial | No | No | Partial | No | No | No | Yes | No | No | Yes | No | Partial | Yes |
| Bernard-Opitz, Sriram, & Nakhoda-Sapuan (2001) | Yes | No | No | Partial | No | No | No | No | No | Yes | Partial | No | No | Yes |
| Bölte et al. (2002) | Yes | Yes | No | Partial | Partial | No | No | No | No | Partial | No | No | No | Partial |
| Bölte et al. (2006) | Yes | Yes | Partial | Partial | Partial | No | No | Partial | No | Yes | Yes | No | Yes | Yes |
| Bölte et al. (2015) | Yes | Partial | Yes | Yes | No | No | No | Yes | No | Yes | Yes | Yes | Yes | Yes |
| Cheng et al. (2018) | Yes | Yes | Yes | Partial | Partial | No | No | Partial | No | Yes | Yes | Partial | Yes | Yes |

| Author (Year) | Criteria for quality assessment of included studies | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Question/objective sufficiently described? | Study design evident and appropriate? | Method of subject/comparison group selection or source of information/input variables described | Subject and comparison group characteristics sufficiently described? | If interventional and random allocation was possible, was it described? | If interventional and blinding of investigators was possible. was it | If interventional and blinding of subjects was possible, was it reported? | Outcome and exposure measure(s) well defined and robust to measurement/misclassification bias? Means of assessment reported? | Sample size appropriate? | Analytic methods described and appropriate? | Some estimate of variance is reported for the main results? | Controlled for confounding? | Results reported in sufficient detail? | Conclusions supported by the result? |
| Faja, et al. (2008) | Yes | Partial | Partial | Yes | No | No | No | Partial | No | Yes | Partial | Yes | No | Yes |
| Faja et al. (2012) | Yes | Yes | Yes | Yes | Partial | No | No | Partial | No | Partial | Partial | Yes | Partial | Yes |
| Fletcher-Watson et al. (2015) | Yes | Yes | Yes | Yes | Yes | Partial | No | Yes | Yes | Yes | Yes | Partial | Yes | Yes |
| Friedrich et al. (2015) | Yes | Partial | Partial | Yes | Partial | No | No | Yes | No | Yes | Yes | Yes | Partial | Yes |
| Friedenson-Hayo et al. (2017) | Yes | Yes | Partial | Yes | Partial | No | No | Partial | Yes | Yes | Yes | Yes | Yes | Yes |
| Golan & Baron-Cohen (2006)-1 | Yes | Partial | Yes | Yes | No | Partial | No | Yes | Yes | Yes | Yes | Yes | Partial | Yes |
| Golan & Baron-Cohen (2006)-2 | Yes | Partial | Yes | Yes | No | Partial | No | Yes | Partial | Yes | Yes | Yes | Yes | Yes |
| Gordon et al. (2014) | Yes | No | Yes | Partial | No | No | No | Partial | No | Yes | Yes | Partial | Yes | Yes |
| Hopkins et al. (2011) | Yes | Yes | Yes | Yes | Partial | Partial | No | Yes | Partial | Yes | Yes | Partial | Yes | Yes |
| Jeffries et al. (2016) | Yes | No | No | No | No | Yes | No | Partial | No | No | No | No | No | Yes |
| Jouen et al. (2017) | Yes | Yes | Yes | Yes | No | No | No | Yes | Partial | Yes | Yes | Yes | Yes | Yes |

| Author (Year) | Criteria for quality assessment of included studies | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Question/objective sufficiently described? | Study design evident and appropriate? | Method of subject/comparison group selection or source of information/input variables described | Subject and comparison group characteristics sufficiently described? | If interventional and random allocation was possible, was it described? | If interventional and blinding of investigators was possible, was it | If interventional and blinding of subjects was possible, was it reported? | Outcome and exposure measure(s) well defined and robust to measurement/misclassification bias? Means of assessment reported? | Sample size appropriate? | Analytic methods described and appropriate? | Some estimate of variance is reported for the main results? | Controlled for confounding? | Results reported in sufficient detail? | Conclusions supported by the result? |
| LaCava et al. (2007) | Yes | No | Yes | Yes | No | No | No | Yes | No | Yes | Yes | No | Partial | Yes |
| Lacava et al. (2010) | Yes | No | Partial | Partial | No | No | No | Yes | No | No | No | No | Partial | Yes |
| Lopata et al. (2016) | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Partial | Yes | Yes | Yes | Yes | Yes |
| Malinverni et al. (2017) | Yes | No | Partial | Partial | No | No | No | No | No | No | No | No | Partial | Yes |
| Miller et al. (2017) | Yes | No | No | No | NA | No | NA | No | No | No | No | No | Partial | Yes |
| Rice et al. (2015) | Yes | Yes | Partial | Yes | Partial | Yes | No | Yes | Partial | Yes | Yes | No | Yes | Yes |
| Russo-Ponsaran et al. (2014) | Yes | No | Yes | Yes | No | No | No | Yes | No | No | Partial | No | Yes | Yes |
| Russo-Ponsaranet al. (2016) | Yes | Yes | Yes | Yes | Partial | Partial | No | Yes | No | Yes | Yes | Partial | Partial | Yes |
| Serret et al. (2014) | Yes | Partial | Yes | Yes | No | Partial | No | Partial | Partial | Yes | Yes | No | Yes | Yes |
| Silver & Oakes (2001) | Yes | Yes | Partial | Partial | Partial | No | No | Partial | No | Yes | Partial | No | Partial | Yes |
| Swettenham (1996) | Partial | No | Partial | Partial | No | No | No | Partial | No | No | Partial | Partial | No | Yes |

| Author (Year) | Criteria for quality assessment of included studies | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Question/objective sufficiently described? | Study design evident and appropriate? | Method of subject/comparison group selection or source of information/input variables described | Subject and comparison group characteristics sufficiently described? | If interventional and random allocation was possible, was it described? | If interventional and blinding of investigators was possible. was it | If interventional and blinding of subjects was possible, was it reported? | Outcome and exposure measure(s) well defined and robust to measurement/misclassification bias? Means of assessment reported? | Sample size appropriate? | Analytic methods described and appropriate? | Some estimate of variance is reported for the main results? | Controlled for confounding? | Results reported in sufficient detail? | Conclusions supported by the result? |
| Tanaka et al. (2010) | Yes | Yes | Yes | Yes | Partial | No | No | Partial | Yes | Yes | Partial | Yes | No | Partial |
| Thomeer et al. (2011) | Partial | Partial | Yes | Yes | No | No | No | Yes | No | Partial | Yes | Yes | Yes | Yes |
| Thomeer et al. (2015) | Yes | Yes | Yes | Yes | Yes | No | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| White et al. (2018) | Yes | Yes | Partial | Yes | NA | No | NA | Partial | Partial | No | No | Partial | No | Yes |

# Appendix F: Funnel plots

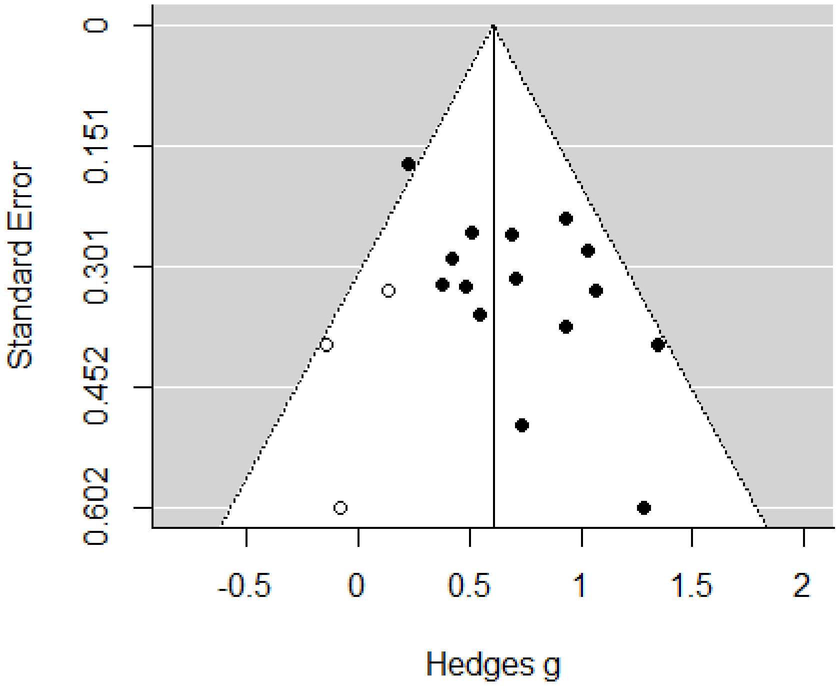


**Figure F.1. Close generalisation outcomes trim and fill funnel plot.**

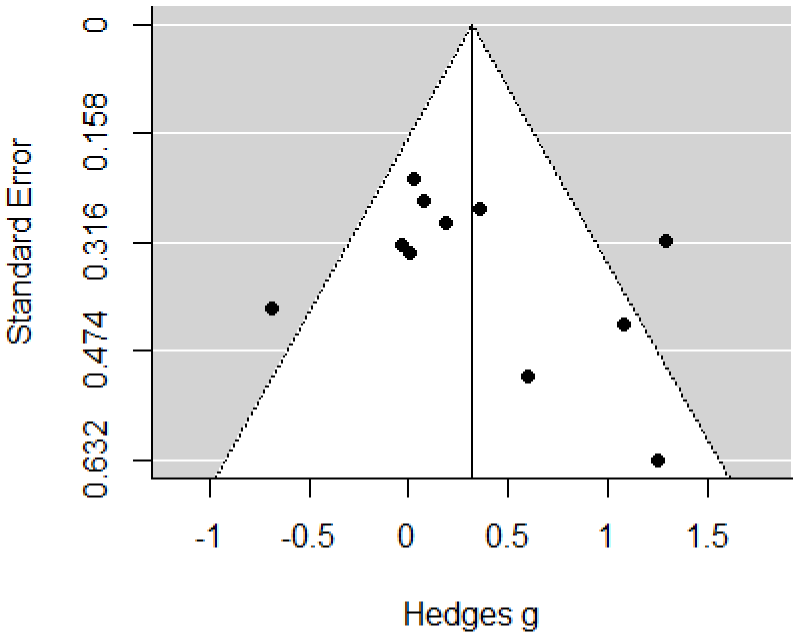


**Figure F.2. Transferability outcomes funnel plot.**

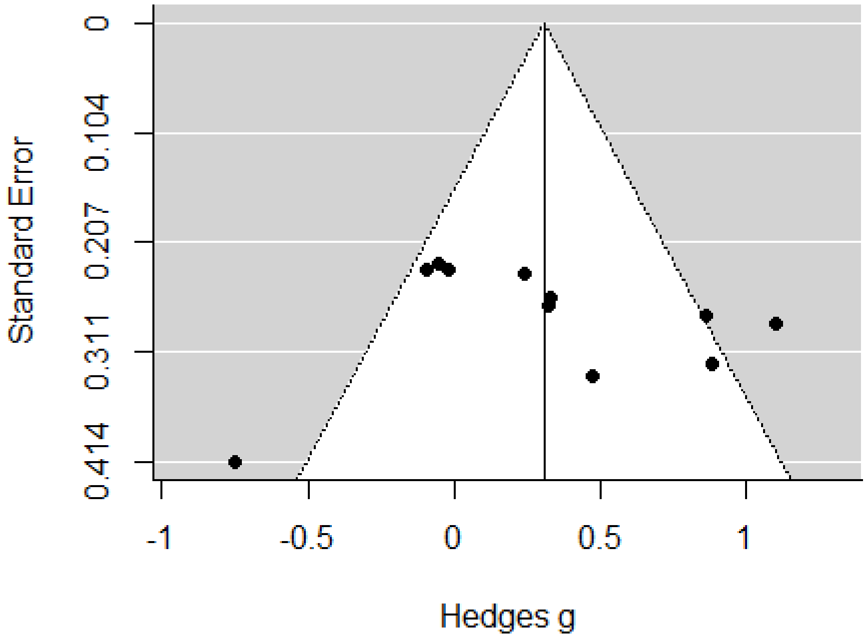


**Figure F.3. Maintenance outcomes funnel plot.**

# Appendix G: Focus group sample game storyline

'An old scientist, who is currently stationed on Planet Mars would like to send a message back to Planet Earth. Due to his age, he is not able to physically travel back to Earth. So, he has invented a robot to help him to complete this mission. As the robot will need to navigate social interactions while on Earth, he has built a microchip for the robot which will contain all the necessary abilities to recognise emotions. The microchip, C.H.I.P., acts as the robot's 'sidekick' and helps the robot to recognise emotions.'

# Appendix H: Mind Reading program satisfaction questionnaire

## *Overall scale*

| | | | | |
|---|---|---|---|---|
| I found the Mind Reading© program was ***helpful*** for me to learn how others are feeling. | 1 | 2 | 3 | 4 |
| I felt that the Mind Reading© program was a ***meaningful*** tool for me learn about emotions. | 1 | 2 | 3 | 4 |
| I thought that it was ***realistic*** *to expect* people to use the Mind Reading© program for 1-2 hours per week, over ten weeks. | 1 | 2 | 3 | 4 |
| I felt that the Mind reading© program was a ***relevant*** tool for me to learn about emotions. | 1 | 2 | 3 | 4 |
| I found that it was easy to ***use and understand*** the Mind Reading© program. | 1 | 2 | 3 | 4 |
| I feel it would be helpful to have support from a mentor while using the Mind Reading© program. | 1 | 2 | 3 | 4 |
| I think including a **story** into the Mind Reading© program will make it more motivating. | 1 | 2 | 3 | 4 |
| Overall, I am ***satisfied*** with the Mind Reading© program. | 1 | 2 | 3 | 4 |
| Overall, I **enjoyed** using the Mind Reading© program. | 1 | 2 | 3 | 4 |

SCALE: 1 = STRONGLY DISAGREE, 2 = DISAGREE, 3 = AGREE, 4 = STRONGLY AGREE

## *Storyline*

1. Please provide some examples why you would like or not like a story to be included in the Mind Reading© program.

2. If you would prefer a story in the game, please provide some examples of stories that would be motivating. (For example, the genre of the story, what happens, who is involved?)

## *Effectiveness*

1. What was **most helpful** for you in the Mind Reading© program? Please provide some examples. (Prompts: Emotion Library, Learning Centre, Game Zone)

2. What was **least helpful** for you in the Mind Reading© program? Please provide some examples. (Prompts: Emotion Library, Learning Centre, Game Zone)

## *Enjoyment*

1. What did you **like** about the Mind Reading© program? Please provide some examples.

2. What did you **not like** about the Mind Reading© program? Please provide some examples.

## *Other comments*

1. What recommendations would you suggest to improve the Mind Reading© program?

2. Any other comments about the Mind Reading© program?

# Appendix I: MindChip$^{TM}$ program satisfaction questionnaire

## *Overall scale*

| | | | | |
|---|---|---|---|---|
| I found the MindChip$^{TM}$ program was a ***helpful*** tool for me to learn how others are feeling. | 1 | 2 | 3 | 4 |
| I felt that the MindChip$^{TM}$ program was a ***meaningful*** tool for me to help learn about emotions. | 1 | 2 | 3 | 4 |
| I thought that it was ***realistic*** for people to attend the MindChip$^{TM}$ program for 1 hour per week, over ten weeks. | 1 | 2 | 3 | 4 |
| I felt that the MindChip$^{TM}$ program was a ***relevant*** tool for me to learn about emotions. | 1 | 2 | 3 | 4 |
| I found it was easy ***understand and complete*** the activities in the MindChip$^{TM}$ program. | 1 | 2 | 3 | 4 |
| I felt that it was helpful to have ***support from a mentor***. | 1 | 2 | 3 | 4 |
| I felt that the MindChip$^{TM}$ program facilitated my ***goal achievement***. | 1 | 2 | 3 | 4 |
| I found the content of MindChip$^{TM}$ is ***applicable*** for my everyday life. | 1 | 2 | 3 | 4 |
| I found it **easy to use ZOOM** during the MindChip$^{TM}$ program. | 1 | 2 | 3 | 4 |
| Overall, I am ***satisfied*** with the MindChip$^{TM}$ program. | 1 | 2 | 3 | 4 |
| Overall, I did **enjoy** the MindChip$^{TM}$ program. | 1 | 2 | 3 | 4 |

SCALE: 1 = STRONGLY DISAGREE, 2 = DISAGREE, 3 = AGREE, 4 = STRONGLY AGREE

## *Effectiveness*

1. What was most helpful for you in the MindChip$^{TM}$ program? Please provide some examples. (Prompts: Video and picture based discussions, MindChip tools, Mind Reading Toolbox, Mind Reading Lightbulb, Action Planning, mentor)

2. What was least helpful for you in the MindChip$^{TM}$ program? Please provide some examples. (Prompts: Video and picture based discussions, MindChip tools, Mind Reading Toolbox, Mind Reading Lightbulb, Action Planning, mentor)

## *Enjoyment*

1. What did you like about the MindChip$^{TM}$ program? Please provide some examples.

2. What did you not like about the MindChip$^{TM}$ program? Please provide some examples.

## *Generalisation*

1. Did you use anything in MindChip$^{TM}$ in your everyday life? If yes, please provide some examples.

## *Goal achievement*

1. Did you set any goals during the MindChip$^{TM}$ program? If yes, did you achieve any of these goals?

## *Accessibility*

1. Can you describe how was it using ZOOM during the MindChip$^{TM}$ program? (Prompts: Setting up the software, instructions, technical issues, video and voice quality)

## *Other comments*

1. What recommendations would you suggest to improve the MindChip$^{TM}$ program?

2. Any other comments about the MindChip$^{TM}$ program?

# Appendix J: Serious game scale

The next few questions explores your experience and feedback for the Mind Reading© Program. For each statement, please choose the number that best describes your opinion about the Mind Reading© Program. If none of the options are exactly right, you can choose the number closest to your opinion.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1. | I felt that the story of the program was motivating and it encouraged me to continue playing the game | 1 | 2 | 3 | 4 | 5 | 6 |
| 2. | I think that the interaction with other characters and/or objects in the program was motivating<br>*Comments:* | 1 | 2 | 3 | 4 | 5 | 6 |
| 3. | I felt that the goals (short term and long term) of the game were clear and easy to understand<br>*Comments:* | 1 | 2 | 3 | 4 | 5 | 6 |
| 4. | The challenge of the game was at the right level for me. The program was not 'too easy' or 'too difficult'<br>*Comments:* | 1 | 2 | 3 | 4 | 5 | 6 |
| 5. | I felt that the difficulty of the program increased as I progressed through the levels<br>*Comments:* | 1 | 2 | 3 | 4 | 5 | 6 |
| 6. | I felt that the rewards used in the program were motivating<br>*Comments:* | 1 | 2 | 3 | 4 | 5 | 6 |
| 7. | The feedback given during the program was understandable and helpful for me to progress in the game<br>*Comments:* | 1 | 2 | 3 | 4 | 5 | 6 |
| 8. | I think that the program provided enough choices for me to decide what I would like to do in the game<br>*Comments:* | 1 | 2 | 3 | 4 | 5 | 6 |
| 9. | I felt like I was in control when completing the tasks of the program<br>*Comments:* | 1 | 2 | 3 | 4 | 5 | 6 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 10. | I felt like I had the freedom to do what I wanted to do in the program<br>*Comments:* | 1 | 2 | 3 | 4 | 5 | 6 |

SCALE: 1 = STRONGLY DISAGREE to 6 = STRONGLY AGREE

Any other comments?

# Appendix K: Emotion Recognition Self-Efficacy Scale

Please rate your answers on the scale from 1 to 10.

1. Not at all confident
5. Moderately confident
10. Very Confident

---

1. How confident are you that you can recognise when someone else is feeling **happy**?
   a) *With your family members?*

      1 5 10

   b) *With your friends?*

      1 5 10

   c) *With strangers?*

      1 5 10

2. How confident are you that you can recognise when someone else is feeling **sad**?
   a) *With your family members?*

      1 5 10

   b) *With your friends?*

      1 5 10

   c) *With strangers?*

1 5 10

3. How confident are you that you can recognise when someone else is feeling **disgusted**?
    a) *With your family members?*

    1 5 10

    b) *With your friends?*

    1 5 10

    c) *With strangers?*

    1 5 10

4. How confident are you that you can recognise when someone else is feeling **surprised**?
    a) *With your family members?*

    1 5 10

    b) *With your friends?*

    1 5 10

    c) *With strangers?*

    1 5 10

5. How confident are you that you can recognise when someone else is feeling **angry**?
    a) *With your family members?*

1 5 10

b) *With your friends?*

1 5 10

c) *With strangers?*

1 5 10

6. How confident are you that you can recognise when someone else is feeling **fearful/afraid**?

   a) *With your family members?*

1 5 10

b) *With your friends?*

1 5 10

c) *With strangers?*

1 5 10

7. How confident are you that you can recognise when someone else is **joking**?

   a) *With your family members?*

1 5 10

b) *With your friends?*

1 5 10

c) *With strangers?*

1 5 10

8. How confident are you that you can recognise when someone else is feeling **excited**?

   a) *With your family members?*

1 5 10

   b) *With your friends?*

1 5 10

   c) *With strangers?*

1 5 10

9. How confident are you that you can recognise when someone else is feeling **bored**?

   a) *With your family members?*

1 5 10

   b) *With your friends?*

1 5 10

   c) *With strangers?*

1 5 10

10. How confident are you that you can recognise when someone else is feeling **interested**?
    a) *With your family members?*

1 5 10

    b) *With your friends?*

1 5 10

    c) *With strangers?*

1 5 10

11. How confident are you that you can recognise when someone else is feeling **worried**?
    a) *With your family members?*

1 5 10

    b) *With your friends?*

1 5 10

    c) *With strangers?*

1 5 10

12. How confident are you that you can recognise when someone else is feeling **sneaky**?
    a) *With your family members?*

1 5 10

b) *With your friends?*

1 5 10

c) *With strangers?*

1 5 10

13. How confident are you that you can recognise when someone else is feeling **hurt**?
    a) *With your family members?*

1 5 10

b) *With your friends?*

1 5 10

c) *With strangers?*

1 5 10

14. How confident are you that you can recognise when someone else is feeling **unfriendly**?
    a) *With your family members?*

1 5 10

b) *With your friends?*

1 5 10

c) *With strangers?*

1 5 10

15. How confident are you that you can recognise when someone else is feeling **kind**?

    a) *With your family members?*

1 5 10

    b) *With your friends?*

1 5 10

    c) *With strangers?*

1 5 10

16. How confident are you that you can recognise when someone else is feeling **frustrated**?

    a) *With your family members?*

1 5 10

    b) *With your friends?*

1 5 10

    c) *With strangers?*

1 5 10

17. How confident are you that you can recognise when someone else is feeling **ashamed**?
    a) *With your family members?*

1 5 10

    b) *With your friends?*

1 5 10

    c) *With strangers?*

1 5 10

18. How confident are you that you can recognise when someone else is feeling **proud**?
    a) *With your family members?*

1 5 10

    b) *With your friends?*

1 5 10

    c) *With strangers?*

1 5 10

19. How confident are you that you can recognise when someone else is feeling **disappointed**?
    a) *With your family members?*

1 5 10

b) *With your friends?*

1 5 10

c) *With strangers?*

1 5 10

20. How confident are you that you can recognise when someone else is feeling **jealous**?
    a) *With your family members?*

1 5 10

b) *With your friends?*

1 5 10

c) *With strangers?*

1 5 10

21. How confident are you in your ability to recognise **other emotions** that were not targeted in the game?
    a) *With your family members?*

1 5 10

b) *With your friends?*

1 5 10

c) *With strangers?*

1 5 10

22. How confident are you that you can identify different **clues from the face** *(e.g. eye and mouth movements)* to help you understand how other people are feeling?
    a) *With your family members?*

1 5 10

b) *With your friends?*

1 5 10

c) *With strangers?*

1 5 10

23. How confident are you that you can identify different **clues from the voice** *(e.g. tone and rate of voice)* to help you understand how other people are feeling?
    a) *With your family members?*

1 5 10

b) *With your friends?*

1 5 10

c) *With strangers?*

1 5 10

24. How confident are you that you can identify different **clues from the body** *(e.g. sweat, body posture, hand movements)* to help you understand how other people are feeling?

   a) *With your family members?*

1 5 10

   b) *With your friends?*

1 5 10

   c) *With strangers?*

1 5 10

25. How confident are you that you can identify different **clues from the social situation** *(e.g. upset as she/he just failed an exam)* to help you understand how other people are feeling?

   a) *In a familiar environment*

1 5 10

   b) *In a new environment*

1 5 10

26. How confident are you that you can identify different **clues from the environment** *(e.g. upset due to a broken glass)* to help you understand how other people are feeling?

   a) *In a familiar environment*

1 5 10

*b) In a new environment*

1 5 10

27. How confident are you that you can find strategies to understand how others are feeling?
    a) *With your family members?*

1 5 10

    b) *With your friends*

1 5 10

    c) *With strangers*

1 5 10

28. How confident are you in your ability to understand how people interact in social environments?
    a) *In a familiar environment*

1 5 10

    b) *In a new environment*

1 5 10

29. How confident are you that you are able to use the skills you learnt in the game in real life social situations?

# Appendix L: Human Research Ethics approval letters

Curtin University

**Memorandum**

| | |
|---|---|
| **To** | Dr Chiara Horlin, School of Occupational Therapy and Social Work |
| **From** | Professor Stephan Millett, Chair, Human Research Ethics Committee |
| **Subject** | Protocol Approval **HR 52/2012** |
| **Date** | 6 June 2012 |
| **Copy** | Professor Torbjorn Falkmer, School of Occupational Therapy and Social Work<br>Associate Professor Tele Tan, School of Electrical Engineering and Computing |

Office of Research and Development
**Human Research Ethics Committee**

**TELEPHONE** 9266 2784
**FACSIMILE** 9266 3793
**EMAIL** hrec@curtin.edu.au

Thank you for your application (4260) submitted to the Human Research Ethics Committee (HREC) for the project titled "*Looking, seeing and hearing social information*". Your application has been reviewed by the HREC and is **approved**.

- You have ethics clearance to undertake the research as stated in your proposal.
- The approval number for your project is **HR 52/2012.** *Please quote this number in any future correspondence.*
- Approval of this project is for a period of twelve months **05-06-2012** to **05-06-2013**. To renew this approval a completed Form B (attached) must be submitted before the expiry date **05-06-2013**.
- Your project has the following special conditions: NIL

**Applicants should note the following:**

It is the policy of the HREC to conduct random audits on a percentage of approved projects. These audits may be conducted at any time after the project starts. In cases where the HREC considers that there may be a risk of adverse events, or where participants may be especially vulnerable, the HREC may request the chief investigator to provide an outcomes report, including information on follow-up of participants.

The attached **FORM B** should be completed and returned to the Secretary, HREC, C/- Office of Research & Development:
When the project has finished, or
- If at any time during the twelve months changes/amendments occur, or
- If a serious or unexpected adverse event occurs, or
- 14 days prior to the expiry date if renewal is required.
- An application for renewal may be made with a Form B three years running, after which a new application form (Form A), providing comprehensive details, must be submitted.

[redacted]
Chair Human Research Ethics Committee

## MEMORANDUM

Curtin University

| | |
|---|---|
| To: | A/Prof Sonya Girdler<br>School of Occupational Therapy and Social Work |
| CC: | Julia Tang, Melissa Black |
| From | Professor Peter O'Leary, Chair HREC |
| Subject | Ethics approval<br>Approval number: HR38/2016 |
| Date | 09-Mar-16 |

Office of Research and Development
Human Research Ethics Office

TELEPHONE 9266 2784
FACSIMILE 9266 3793
EMAIL hrec@curtin.edu.au

Thank you for your application submitted to the Human Research Ethics Office for the project: 6567

Evaluation of a Computer-based Emotion Recognition Intervention among Individuals on the Autism Spectrum

Your application was reviewed by Human Research Ethics Committee at Curtin University at their meeting on the 02/02/2016

Thankyou for providing the additional information requested by the Human Research Ethics Committee. The information you provided was satisfactory and your proposal is now approved.

Please note the following conditions of approval:

1. Approval is granted for a period of four years for **10-Mar-16** to **10-Mar-20**
2. Research must be conducted as stated in the approved protocol.
3. Any amendments to the approved protocol must be approved by the Ethics Office.
4. An annual progress report must be submitted to the Ethics Office annually, on the anniversary of approval.
5. All adverse events must be reported to the Ethics Office.
6. A completion report must be submitted to the Ethics Office on completion of the project.
7. Data must be stored in accordance with WAUSDA and Curtin University policy.
8. The Ethics Office may conduct a randomly identified audit of a proportion of research projects approved by the HREC.

Should you have any queries about the consideration of your project please contact the Ethics Support Officer for your faculty, or the Ethics Office at hrec@curtin.edu.au or on 9266 2784. All human research ethics forms and guidelines are available on the ethics website.

Yours sincer[redacted]

Professor P[redacted]
Chair, Human Research Ethics Committee

# Appendix M: Participant information sheets and consent forms

## What do you want in a Computer Game?

One important skill in everyday social situations includes the ability to recognise other people's feelings. In our upcoming study, we are going to develop a computer game for adolescents and young adults to learn what other people are feeling.

**We need your help!**
To help us with the development of the computer game, we are looking for adolescents and/or adults with Autism Spectrum Conditions to participate in an interview or a focus group. This interview or focus group aims to look at what YOU want in a computer game. We would like to understand the things that you would like or do not like in a computer game.

**What does it involved?**
Completing a one on one interview or participating in a group of approximately five individuals on what you think about computer games. Each interview or focus group will take about an hour to one hour and a half.

To assist us with this study, the interviews and focus groups will be audio recorded. However, all information collected in this study will be recorded without names or any identifying information. Only the researcher will have access to the completed tasks, and your individual results will not be reported. No individual results/information will be published and group data will only be published as scientific papers or conference presentations. Participation in this study is entirely voluntary, and you will be free to withdraw from the research at any time, without providing reason or justification. In this case, any results or records of your participation will be destroyed, unless you agree otherwise.

Please do not hesitate to contact the researchers, Julia Tang or Melissa Black (details below) or Associate Prof. Sonya Girdler (+618 9266 3630) if you have any questions regarding the research project.

Melissa Black
PhD Canditate
School of Occupational Therapy and Social Work
**Phone** 0409 109 816
**Email** melissa.black@curtin.edu.au

Julia Tang
PhD Candidate
School of Occupational Therapy and Social Work
**Phone** 0433 599 877
**Email** julia.tang@curtin.edu.au

Sonya Girdler
Associate Professor
School of Occupational Therapy and Social Work

This research has been reviewed and given approval by the Curtin University Human Research Ethics Committee (approval HR 52/2012). Should you wish to make a complaint on ethical grounds, please contact the Human Ethics Committee (Secretary), phone: 9266 2784, email: hrec@curtin.edu.au, mail: C/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth WA 6845

CONSENT FORM

## What do you want in a Computer Game?

I …………………………………..have read the information provided concerning this study, and any questions I have asked have been answered to my satisfaction.

❒ I agree to participate in this activity, realising that it is completely voluntary and my son/daughter may withdraw at any time without reason and without prejudice.

❒ I understand that all information provided will be treated as strictly confidential, and will not be released by the investigator unless required by law.

❒ I have been advised as to what data are being collected, what the purpose is, and what will be done with the data upon completion of the research.

❒ I agree that research data gathered for the study may be published provided that neither my and my child's name, nor other identifying information, is used.

❒ I agree for the interview/focus group to be audio recorded. I understand that all audio recordings will be deidentified and kept confidential.

❒ I agree to allow access to my son's/daughter's medical records where the diagnosis of Asperger's syndrome/Autism Spectrum Disorder is confirmed to assist us in this study.

(Parent) Name & Signature : ………………………………………………….

(Participant) Name & Signature : ………………………………………………….

Contact number : ………………………………………………….

Email address : ………………………………………………….

Date : ………………………………………………….

This research has been reviewed and given approval by the Curtin University Human Research Ethics Committee (approval HR 52/2012). Should you wish to make a complaint on ethical grounds, please contact the Human Ethics Committee (Secretary), phone: 9266 2784, email: hrec@curtin.edu.au, mail: C/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth WA 6845

Melissa Black/Julia Tang

School of Occupational Therapy & Social Work
Curtin University
GPO Box U1987
Perth, Western Australia, 6845
**Telephone** +61409 109 816 /+61433 599 877
**Email** melissa.black@curtin.edu.au
julia.tang@curtin.edu.au

# Looking, Seeing and Hearing Social Information

In most everyday situations objects and environments are perceived through our senses and we receive information from more than one sense at any given time. The way we process and integrate this information is essential to how we engage in all activities in daily life. This experiment will explore visual ('seeing') and auditory ('hearing') processing of social information (faces and voices) using eye tracking (ET) and electroencephalography (EEG).

Your participation in this study will take approximately 4 hours and will involve completing a series of computer tasks whilst wearing an EEG cap (left). The EEG cap will be fitted to your head like a loose swimming cap. This process is completely safe and non-invasive and after the experiment you will be able to shower to remove the gel paste from your hair. The eye tracker (pictured right) will be used to record your eye movements. After that, you will be standing on a 'force platform' to see how your vision impacts on your balance. You will also be asked to complete some cognitive tasks that involve verbal questions, looking at picture puzzles and building patterns from blocks as well as questions relating to different social stories.

Eye Tracker

Force platform

All information collected in this study will be recorded without names or any other identifying information. Only the researcher will have access to the completed tasks, and your individual results will not be reported. To assist us with this study, access your diagnostic reports. No individual results/information will be published and group data will only be published as scientific papers or conference presentations. Participation in this study is entirely voluntary, and you will be free to withdraw from the research at any time, without providing reason or justification. In this case, any results or records of your participation will be destroyed, unless you agree otherwise.
As a reimbursement for your time and participation, you will receive either 2 adult movie tickets OR a $40 Coles/Myer gift card as well as a free meal during the break.

Please do not hesitate to contact the researchers, Melissa Black or Julia Tang (details above) or Associate Prof. Sonya Girdler (+618 9266 3630) if you have any questions regarding the research project.

Melissa Black
PhD Canditate
School of Occupational Therapy and Social Work

Julia Tang
PhD Candidate
School of Occupational Therapy and Social Work

Sonya Girdler
Associate Professor
School of Occupational Therapy and Social Work

This research has been reviewed and given approval by the Curtin University Human Research Ethics Committee (approval numberSMEC-73-10, OTSW-03-2011 and OTSW-10-2011).). Should you wish to make a complaint on ethical grounds, please contact the Human Ethics Committee (Secretary), phone: 9266 2784, email: hrec@curtin.edu.au, mail: C/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth WA 6845

Melissa Black/Julia Tang

School of Occupational Therapy & Social Work
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GPO Box U1987
Perth, Western Australia, 6845
**Telephone** +61409 109 816 /+61433 599 877
**Email** melissa.black@curtin.edu.au
julia.tang@curtin.edu.au

CONSENT FORM

Looking, Seeing and Hearing Social Information

I …………………………………..have read the information provided concerning this study, and any questions I have asked have been answered to my satisfaction.

❒ I agree to participate in this activity, realising that I may withdraw at any time without reason and without prejudice.

❒ I understand that all information provided will be treated as strictly confidential, and will not be released by the investigator unless required by law. I have been advised as to what data are being collected, what the purpose is, and what will be done with the data upon completion of the research.

❒ I agree that research data gathered for the study may be published provided that neither my name, nor other identifying information, is used.

❒ I agree to allow access to my medical record where the diagnosis of Asperger's syndrome/Autism Spectrum Disorder is confirmed.

Name & Signature : ………………………………………………….

Contact number : ………………………………………………….

Email address : ………………………………………………….

Date : ………………………………………………….

This research has been reviewed and given approval by the Curtin University Human Research Ethics Committee (approval number HR 52/2012). Should you wish to make a complaint on ethical grounds, please contact the Human Ethics Committee (Secretary), phone: 9266 2784, email: hrec@curtin.edu.au, mail: C/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth WA 6845

Curtin University

*Computer-based Emotion Recognition Training*

**PARTICIPANT INFORMATION STATEMENT**

| | |
|---|---|
| **HREC Project Number:** | HR38/2016 |
| **Project Title:** | Do Computer Games and Biofeedback Help in Improving Emotion Recognition Skills? |
| **Principal Investigator:** | Associate Professor Sonya Girdler<br>Associate Professor of Occupational Therapy (Research) |
| **Student researcher:** | Melissa Black (PhD candidate)<br>Julia Tang (PhD candidate) |
| **Version Number:** | 1 |
| **Version Date:** | 07.03.2016 |

**What is the Project About?**

Emotion recognition is an important skill for every day social situations, such as in relationships, university and the workplace. We understand that this skill may be difficult for some people on the autism spectrum.

We know that some regions of the brain and where we look are important to help us to process and understand the emotions of others. This research project aims to investigate the effectiveness of a computer game integrated with biofeedback to improve emotion recognition skills among adults on the autism spectrum. Biofeedback uses electroencephalography (EEG) *(pictured left)* and eye tracking to measure brain wave activity and eye gaze patterns. This information will be converted into visual feedback in the computer game. The person is then able to control this feedback to improve their brainwave function and visual search strategies when recognising an emotion.

Eye Tracker

**Who is doing the Research?**

This research project is funded by the Cooperative Research Centre for Living with Autism Spectrum Disorders (Autism CRC). This project is being conducted in the School of Occupational Therapy and Social Work, by Associate Professor Sonya Girdler (principal investigator), Melissa Black and Julia Tang. Melissa and Julia are PhD candidates funded by Curtin University and the Autism CRC. They will be using the results of this research project to obtain a Doctor of Philosophy at Curtin University.

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**Why am I being asked to take part and what will I have to do?**
We are looking for adults on the autism spectrum with a formal diagnosis of High Functioning Autism or Asperger's Syndrome or PDD-NOS to take part in this research study. To assist us with this, we may need to sight your diagnostic reports to confirm the diagnosis of autism.

This study will take place at Curtin University. During the first session, you will be asked to complete a set of questionnaires which will include questions on your socio-demographics, medical history, and social behaviours. You will also be asked to complete a set of computer-based tasks to understand your ability to complete social and emotional tasks. You will be wearing an EEG cap which will be fitted on your head like a loose swimming cap with some gel on your hair. The eye tracker will be used to record your eye movements.

You will then be randomly allocated to either the group with biofeedback intervention or a controlled group without biofeedback intervention. This allocation is only known to the researchers. Each participant will receive approximately one hour per week of intervention across six weeks. A few electrodes will be placed on your scalp and ears during the intervention.

Following the intervention (immediate and after 12 weeks), you will complete a few tasks to measure any differences in your ability to understand social and emotional information.

We would like you to consider allowing us to send you information about future research projects. Once you receive the information it is your choice if you decide to take part or not.

**Are there any benefits' to being in the research project?**
The results of this study will assist us in understanding the potential of a computer based intervention (biofeedback and computer game) in improving emotion recognition skills in adults on the autism spectrum.

**Are there any risks, side-effects, discomforts or inconveniences from being in the research project?**
The process of putting on an EEG cap is completely safe and non-invasive. You are able to shower to remove the gel paste from your hair after the session. Although side effects are unlikely, some may experience some side effects from the biofeedback intervention. A few have reported headaches, fatigue, irritability, "feeling spacey" and nausea. Some other major side effects may include seizure, depression, manic attacks, emotional confusion, memory issues and nightmares. Although, these major side effects are reported to less likely to occur. We will be closely monitoring these symptoms during the trial.

If you begin to experience any side effects, please inform the researchers and the testing will be stopped. In an event that you feel unwell to the point that you feel that you are unable to return home safety, a taxi will be called (fare covered by the researchers). If you experience any serious side effects, you will be given immediate medical attention by the first aid officer and the ambulance will be contacted. You will be directed to the Curtin University Health Services (counselling and/or general practitioner), if the symptoms continue to persist after the trial.

There will be no costs to you for participating in this project. As a compensation for your time and travel, you will receive a choice of two Hoyts cinema tickets or a $30 Coles/Myers gift voucher. Since this project will be undertaken at Curtin University, all parking costs will be covered by the researchers. Due to the length of this project, we will be providing frequent breaks with refreshments when required.

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**Who will have access to my information?**
All information collected in this study will be recorded without names or any other identifying information. Each data collected will be assigned a code with the names removed. Only the researchers will have access to the completed tasks, and your individual results will not be reported. If you consent, your de-identified data (summary scores and some socio-demographic information, i.e., age, occupation, diagnosis and gender) from one of the tasks (Movie for Assessment of Social Cognition) will be forwarded to the publishers of the task for validation purposes.

No individual results or information will be published and group data will only be published as scientific papers or conference presentations. All electronic data collected will be password-protected and the hard copies will be stored in a locked storage. All data collected in this study will be kept securely at Curtin University for 7 years after the research has ended and then it will be destroyed.

**Will you tell me the results of the research?**
At the end of this research project, you will be provided with a summary of the results obtained from this study. Results will not be individual but based on all the information we collect and review as part of the research. You are welcomed to request for your individual results, if you like.

**Do I have to take part in the research project?**
Your participation in this study is entirely voluntary, and you will be free to withdraw from the research at any time, without providing reason or justification. If you chose not to take part or withdraw from the study, it will not affect your relationship with the University, staff or colleagues. In this case, any results or records of your participation will be destroyed, unless you agree otherwise.

If you are interested to participate in this research and/or have any questions, please do not hesitate to email any of us (details below) or on our research mobile number 0466 546 142.

**Melissa Black** or **Julia Tang** (PhD candidates): curtincomputergame@gmail.com

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**CONSENT FORM**

| | |
|---|---|
| **HREC Project Number:** | HR38/2016 |
| **Project Title:** | Do Computer Games and Biofeedback Help in Improving Emotion Recognition Skills? |
| **Principal Investigator:** | Associate Professor Sonya Girdler<br>Associate Professor of Occupational Therapy (Research) |
| **Student researcher:** | Melissa Black<br>Julia Tang |
| **Version Number:** | 2 |
| **Version Date:** | 22.04.2016 |

- ☐ I have read, the participant information sheet and I understand its contents.
- ☐ I believe I understand the purpose, extent and possible risks of my involvement in this project.
- ☐ I have had an opportunity to ask questions and I am satisfied with the answers I have received.
- ☐ I understand that this project has been approved by Curtin University Human Research Ethics Committee and will be carried out in line with the National Statement on Ethical Conduct in Human Research (2007).
- ☐ I understand I will receive a copy of this Information Statement and Consent Form.

***Optional consent:***

☐ I do ☐ I do not consent to the researchers accessing my medical record

☐ I do ☐ I do not consent for the researchers to contact my GP/family doctor

*If you do, please provide the contact details of your GP/family doctor below for us to contact if an adverse effect occurs from the training.*

*Name of GP/Family Doctor:* __________________________________

*GP/Family Doctor Contact Details:* __________________________________
:

☐ I do ☐ I do not consent to be contacted about future research projects that are related to this project

*If you do, please provide your contact details below.*

*Email address* __________________________________

*Telephone Number* __________________________________

☐ I do ☐ I do not consent for my de-identified data to be forwarded to a third-party (publishers of the assessment).

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| | |
|---|---|
| Participant Name | |
| Participant Signature | |
| Date | |

Declaration by researcher: I have supplied an Information Letter and Consent Form to the participant who has signed above, and believe that they understand the purpose, extent and possible risks of their involvement in this project.

| | |
|---|---|
| Researcher Name | |
| Researcher Signature | |
| Date | |

# Appendix N: MindChip$^{TM}$ manual

Due to Intellectual Property obligations, claims or restrictions imposed by an external organisation that supported this research, this appendix is permanently exempt from this thesis and cannot be made publicly available online at this time.

Please refer to https://www.autismcrc.com.au/ for further information about the MindChip manual.

# Appendix O: MindChip$^{TM}$ facilitator resources

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A systematic review and meta-analysis of social emotional computer based interventions for autistic individuals using the Serious Game framework.

| | |
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| Journal of Autism and Developmental Disorders | Development and feasibility of MindChipTM: A social emotional telehealth intervention for autistic adults. |
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| 10.1007/s10803-020-04592-3 | Julia Tang |
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Sun Jun 28 02:54:50 CEST 2020

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